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IOWA

GEOLOGICAL SURVEY

VOLUME XII

ANNUAL REPORT, 1901,

WITH

ACCOMPANYING PAPERS.

SAMUEL CALVIN, A. M., PH. D., STATE GEOLOGIST

A. G. LEONARD, ASSISTANT STATE GEOLOGIST

DES MOINES:
PUBLISHED FOR THE IOWA GEOLOGICAL SURVEY
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GEOLOGICAL BOARD.

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GEOLOGICAL BOARD.

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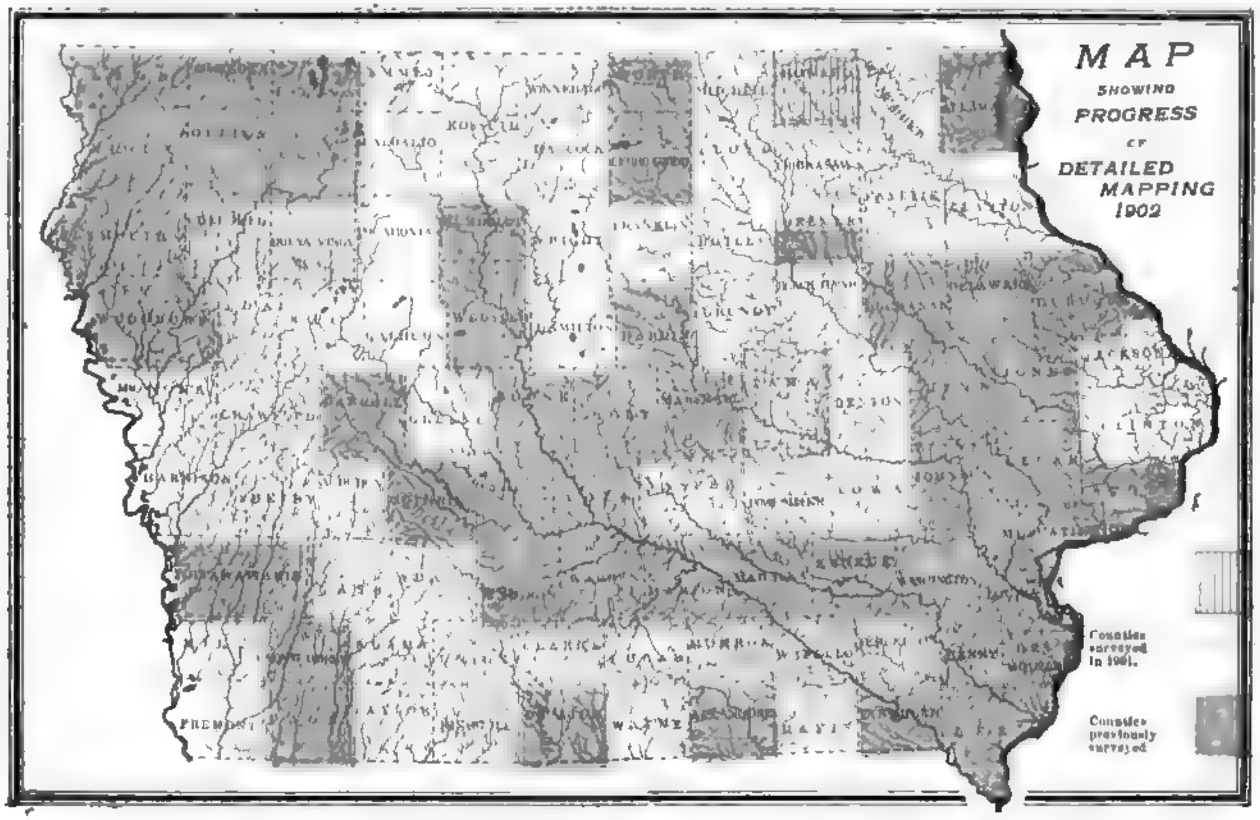
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TENTH ANNUAL

Report of the State Geologist.

IOWA GEOLOGICAL SURVEY,
DES MOINES, DECEMBER 31, 1901.

To Governor Leslie M. Shaw and Members of the Geological Board:

GENTLEMEN:—The work of the Iowa Geological Survey, during the year 1901, has not differed essentially from the work carried on during the years preceding, since the present Survey was organized. Investigations respecting the characteristics and surface distribution of the geological formations of Iowa are not yet complete. The work already done has been purposely scattered so as to gain information concerning each of the important and typical portions of the state; and it may now be claimed that we know in a general and broad way the geological structure at any given point from the surface down to the underlying crystalline rocks; while over more than half the state our knowledge is positive and accurate. Before, however, the study of special subjects for the state as a whole can be taken up with desired thoroughness and success, the geological details for practically every county should be carefully worked out. More than half the work of detailed mapping has been finished. Prior to the year 1901 forty-six counties had been studied with the requisite thoroughness, and reports, accompanied with geological maps, have been published in relation to forty-four. During the year 1901 the geological work was completed in seven counties—namely, Buena Vista, Cherokee, Howard, Jefferson, Monroe, Tama and Wapello; and work has been begun in Adair,

Bremer, Clayton, Fayette, Ida, Sac, Taylor and Winneshiek. Fifty-three counties are now completed, and in eight others the work is more or less advanced.

The regular corps employed in field work in 1901 was made up of Beyer, Calvin, Leonard, Macbride, Norton, Savage, Udden, Wilder and Young; and in addition there were three volunteer assistants, Gow, Mosnat and Schoonover. The members of the regular corps are men whose familiarity with the problems of Iowa geology enables them to carry on their investigations with a thoroughness which overlooks no significant detail, however minute, while at the same time the work is done with a minimum expenditure of time and money.

As stated in the last Administrative Report, some work on special subjects has already been undertaken. Professor Beyer is still at work on his monograph on Iowa clays. Professor Wilder's report on Webster county, which is offered for publication as part of volume XII, is in effect a monograph in which the extent and possibilities of the gypsum deposits of the state are discussed with exhaustive and scientific fullness. The monograph of Leonard in volume VI and the report on Dubuque county in volume X give the results of careful and laborious investigations relating to the genesis and distribution of the lead and zinc ores of Iowa. It is the purpose soon to begin a special study of the building stones, lime burning rocks and other quarry products of the state; and there is planned, for the near future, a monograph on coal, defining the areas in which prospecting may be prosecuted with reasonable hope of success, accurately marking the limits beyond which no coal is possible, pointing out for the various localities the depth beneath which it is useless to carry the prospect holes, describing the manner in which the workable veins are distributed in the coal bearing area, giving determinations with respect to fuel values, and setting forth all other facts which could be of possible service to the miners and users of Iowa coals.

It is a pleasure in this connection to note the verification of the statements made on pages 453 and 458 of volume XI, to the effect that coal mining in Page county is capable of much greater development than it has yet attained, and that the Nodaway coal

seam is certain to be worked in many neighborhoods where it is not yet prospected. A number of new mines have been reported as opened in the county during the past year, and one at least of these is located on state property, on grounds belonging to the Clarinda Hospital for the Insane. The Nodaway seam is unusually persistent and uniform. The prospector can know beforehand with almost absolute certainty, the thickness and the quality of the coal he is to find. The dip is not uniform, and so the exact depth beneath the surface at which the coal will be found at any given point can not be told to a foot, or even to ten feet; but the coal is present over a very large area, and it is so located with reference to the surface that it will be practicable to mine it over at least half the county. This same coal is present over extensive areas in Adams, Montgomery and Taylor counties and will afford fuel to meet all local needs for many years to come.

In addition to the work done in the field, the large amount of purely clerical and administrative work belonging to the office has been kept up to date. The Des Moines office has been managed by the Assistant State Geologist, Mr. A. G. Leonard, with the assistance of the Secretary, Miss Nellie E. Newman. Two volumes have been isued by the Survey during the year—volume XI of the regular series of reports and volume I of the series of Bulletins. The personal attention necessary to getting out these volumes in acceptable form has occupied a large share of the time of the Assistant State Geologist; but in addition to supervising every detail in connection with the preparation and distribution of the volumes, Mr. Leonard has been able to do practically a full season's field work in Wapello county. For a full account of his work in the office and in the field, you are referred to his Administrative Report, which is herewith submitted.

Bulletin No. 1, which is a report on the Grasses of Iowa, by Professors Pammel and Weems of the State College of Agriculture, has been most cordially received by those qualified to judge of its merits, as a welcome and important contribution to practical science. The favor accorded to volume XI has been equally gratifying. The edition of each volume of the geological series is practically exhausted as soon as it is issued. Were all requests

for copies of the reports granted, the edition would have to be more than twice as large as it is.

Accompanying this report I have the honor of submitting for publication, as volume XII of the Iowa Geological Reports, the Mineral Statistics for the year, by S. W. Beyer; the report on Webster county, with a general discussion of the manufacture and uses of gypsum, by Frank A. Wilder; the report on Henry county, by T. E. Savage; the report on Cherokee and Buena Vista counties, by T. H. Macbride; the report on Jefferson county, by J. A. Udden; the report on Wapello county, by A. G. Leonard; and the report on Monroe county, by S. W. Beyer and L. E. Young. The four counties, Henry, Jefferson, Wapello and Monroe, are among the most important in the state. They are all embraced in the Carboniferous area. In the eastern part of the belt which these counties occupy, we have a record of Carboniferous conditions immediately preceding the deposition of coal; in the western part of the area the record is that of conditions the most favorable known in Iowa for coal accumulation. Cherokee and Buena Vista are prairie counties in which the indurated rocks and all for which they may stand are buried under thick sheets of drift. The drift, however, is the youngest and freshest in the state and is unusually rich in all the constituents which go to make up an ideal soil. Through these counties pass the margin of the Wisconsin drift, and the special effects of the forces operative along the margin of the great ice fields of this particular age, so far as they have been instrumental in modifying the topography of the surface and the quality of the soils, have been carefully studied. Webster county, in addition to its coal and other products, embraces our gypsum field. The gypsum deposit is one of very great economic importance; and the subject, in all its aspects, has been studied with the care and thoroughness which its importance deserves. It is believed that the volume as a whole is fully up to the standard of its predecessors, and that it will meet the just expectations of the people of Iowa in providing, in accessible form, definite information respecting the geological structure and geological resources of some of the most important counties in the state. The extent of the work accom-

plished by the Survey since its organization may be inferred from the following list of publications:

VOLUME I. FIRST ANNUAL REPORT, 1892.

480 Pages, 10 Plates, 26 Figures.
Price, in paper, 70 cents; postage, 26 cents.

Contents:

VOLUME II. COAL DEPOSITS.

536 Pages, 18 Plates, 251 Figures.
Price, in paper, 70 cents; postage, 31 cents.

Contents:

VOLUME III. ANNUAL REPORT, 1893.

501 Pages, 37 Plates, 34 Figures.
Price, in cloth, $1.10; postage, 35 cents.
In paper, $1; postage, 30 cents.

Contents:

VOLUME IV. ANNUAL REPORT, 1894.

467 Pages, 11 Plates, 6 Maps, 54 Figures.
Price, in cloth, $1.25; postage, 34 cents.
In paper, $1; postage, 28 cents.

Contents:

VOLUME V. ANNUAL REPORT, 1895.

452 Pages, 14 Plates, 7 Maps, 72 Figures.
Price, in cloth, $1; postage, 34 cents.
In paper, 85 cents; postage, 28 cents.

Contents:

VOLUME VI. LEAD AND ZINC, ARTESIAN WELLS, ETC.

487 Pages, 28 Plates, 57 Figures.
Price, in cloth, 85 cents; postage, 34 cents.
In paper, 70 cents; postage, 28 cents.

Contents:

VOLUME VII. ANNUAL REPORT, 1896.

550 Pages, 11 Plates, 11 Maps, 81 Figures.
Price, in cloth, $1.30; postage, 34 cents.
In paper, $1.15; postage, 32 cents.

Contents:

VOLUME VIII. ANNUAL REPORT, 1897.

427 Pages, 32 Plates, 6 Maps, 13 Figures.
Price, in cloth, $1.30; postage, 30 cents.
In paper, $1.15; postage, 26 cents.

Contents:

VOLUME IX. ANNUAL REPORT, 1898.

572 Pages, 13 Plates, 7 Maps, 56 Figures.
Price, in cloth, $1.45; postage, 36 cents.
In paper, $1.30; postage, 30 cents.

Contents:

Geology of Humboldt County; by T. H. Macbride.
Geology of Story County; by S. W. Beyer.
Geology of Muscatine County; by J. A. Udden.
Geology of Scott County; by W. H. Norton.
Artesian Wells of the Belle Plaine Area; by H. R. Mosnat.

VOLUME X. ANNUAL REPORT, 1899.

666 Pages, 11 Plates, 11 Maps, 102 Figures.
Price, in cloth, $1.85; postage, 40 cents.
In paper, $1.70; postage, 36 cents.

Contents:

Administrative Reports.
Statistics of Mineral Productions; by S. W. Beyer.
Fossil Fauna of the Kinderhook Beds of Burlington; by Stuart Weller.
Geology of Lyon and Sioux Counties; by F. A. Wilder.
Geology of Osceola and Dickinson Counties; by T. H. Macbride.
Geology of Hardin County; by S. W. Beyer.
Geology of Worth County; by Ira A. Williams.
Geology of Dubuque County; by Samuel Calvin and H. F. Bain.

VOLUME XI. ANNUAL REPORT, 1900.

519 Pages, 12 Plates, 9 Maps, 43 Figures.
Price, in cloth, $1.45; postage, 32 cents.

Contents:

Administrative Reports.
Mineral Production of Iowa in 1900; by S. W. Beyer.
Geology of Louisa County; by J. A. Udden.
Geology of Marion County; by B. L. Miller.
Geology of Pottawattamie County; by J. A. Udden.
Geology of Cedar County; by W. H. Norton.
Geology of Page County; by Samuel Calvin.
Geology of Clay and O'Brien Counties; by T. H. Macbride.

The work of our geologists, in co-operation with members of the U. S. Geological Survey, has made Iowa classic ground for the study of problems relating to the drift. The succession of events which took place during that most interesting and most unique of all the divisions of geological time, the Glacial Epoch, is more clearly recorded in Iowa than anywhere else on this continent. It was formerly supposed that there was a single invasion of glacial ice which transported and spread out the great body of drift that covers so large an area in North America; but instead of the single glacial episode recognized by the earlier

observers, there are clear and detailed records of at last five successive ice invasions separated one from the other by long interglacial intervals. Brief notes on the glacial and interglacial stages, as they have been deciphered in Iowa and adjoining states, were published on pages 18 and 19 of volume VII. The facts remain as there stated, but additional facts which have come to light through more careful and detailed studies, particularly through the work of Leverett of the United States Geological Survey, make some changes in the names used in volume VII desirable. The terms employed in the more recent literature of this subject, for the recognized glacial and interglacial stages of the Great Ice Age are:

First glacial stage, *Pre-Kansan* or *Sub-Aftonian*.
  First interglacial stage, *Aftonian*.
Second glacial stage, *Kansan*.
  Second interglacial stage, *Yarmouth*.
Third glacial stage, *Illinoian*.
  Third interglacial stage, *Sangamon*.
Fourth glacial stage, *Iowan*.
  Fourth interglacial stage, *Peorian*.
Fifth glacial stage, *Wisconsin*.

The Wisconsin drift is very much younger than the Kansan or the pre-Kansan. There is an enormous interval between the earliest and the latest of the ice invasions. The earlier glacial and interglacial stages seem to have been longer than those of later date. Some of the interglacial intervals were many times as long as the period which has elapsed since the disappearance from Iowa of the great ice fields which characterized the Wisconsin stage of glaciation. If the time since the Wisconsin is taken as unity, the time since the Kansan is at least twenty; the history of glaciation in Iowa is long, the records are exceedingly complex.

The pre-Kansan drift nowhere expresses itself at the surface; it has been exposed in a few places by the erosion of stream valleys; but the most satisfactory sections, showing the characteristics and relations of this oldest of all the known mantles of till, are found in railway cuts and other artificial excavations. In

the report on Page county, volume XI, pages 411 and 447, there are suggestions that the surface drift of southwestern Iowa may possibly be pre-Kansan. The reasons for making these suggestions were found in the enormous changes which the drift of the region has undergone. The surface of the drift has been deeply eroded. Valleys have been cut in it from 100 to 200 feet in depth and two, three or four miles in width. The whole surface of the country, even on the divides, is deeply carved and trenched; while weathering, measured in all its aspects and effects, has wrought profound changes in the deposit to unusual depths. The whole body of the till is completely altered to depths of forty or fifty feet. Taking all the criteria into consideration, the southwestern drift seems very much older than the Kansan till of southeastern Iowa.

Over the greater part of Iowa the Kansan and pre-Kansan drift sheets are definitely separated by soil beds, peat beds, and the remains of luxuriant forests which flourished in the interglacial interval. At Afton Junction, however, there are heavy beds of gravel between the two sheets of till. This gravel was deposited by the strong currents of water which flowed away from the edge of the pre-Kansan ice during the period when it was melting. Gravel was washed out over that part of the pre-Kansan till from which the slowly wasting and retreating glaciers had withdrawn. Later on, the Kansan ice came and deposited drift above it. But in the mean time a thin soil was developed on the surface of the gravel, and forests grew upon this surface during a long interval of mild climate. It is from this typical locality at Afton Junction that science gets the name Aftonian for the interval between the first and second of the recognized ice invasions of Iowa.

During the season of 1901 the "Burlington" road spent vast sums of money in rectifying its alignment and grades in southwestern Iowa; and the great number of deep cuts which were made in the progress of the work afforded an opportunity to determine definitely the relation of the drift sheets in this part of the state. Taking advantage of this unusual opportunity, the region was visited and a number of the cuts were examined. The fresh sections, showing every detail, but emphasized the original impression that the surface drift of this part of the state shows

unusual age as compared with the oldest drift east of the "water-shed." The whole body of the till, as noted above, is completely changed by weathering to depths of forty or fifty feet. The iron-bearing bowlders, the diabases, basalts, hornblende-bearing rocks and the like—are more or less decayed; and the iron constituent, completely oxidized, stains the deposit and transforms the original blue to various tones of red or brown or yellow, throughout the whole zone of alteration. From the upper part of the section the limestone pebbles have been removed by solution; and the finer limestone flour, which was originally an important part of the drift, has been leached out by descending waters. The whole lime constituent has now been completely segregated to great depths; and, by reason of secondary deposition from solution, it now appears as concretions resembling the well known loess kindchen. The position of these concretionary lime balls is well down in the sides of the cuts, where they are usually arranged in rather definite rows along the cracks or joints which determined the course of the descending waters.

The fresh cuts west of the "watershed" afford opportunities never before presented to the geologist. In the first place, they have opened up and revealed the true character of the drift in the vicinity of Afton Junction as no excavations or natural exposures had ever done before; and in the second place they have made it possible to trace the surface drift sheet with practical continuity for distances of many miles. It may now be demonstrated that it is the old looking drift of southwestern Iowa that overlies the gravels at Afton Junction. In the first cut west of Afton Junction the Aftonian gravels are exposed beneath fifty feet or more of this old and highly altered drift. Notwithstanding all the unmistakable evidence of age which it presents, the surface drift of southwestern Iowa is supra-Aftonian. For the present at least it will have to be correlated with the Kansan drift of the southeastern part of the state. A sheet of true sub-Aftonian or pre-Kansan till is well exposed beneath the gravels in the bluffs of the river valley, about a mile southwest of Afton Junction. As already stated, the sub-Aftonian or pre-Kansan till is exposed in only a very few sections, and these are limited in size; while,

so far as now known, it does not anywhere control the topographic characters of the surface.

Until the past season nothing was positively known concerning the true location of the respective margins of the Iowan and Kansan drift sheets in the territory lying between the north line of Delaware county and the Iowa-Minnesota boundary. The tracing of drift margins has always, in large measure, been made subordinate to broader studies of the geological structure and resources of the region under consideration. During 1901 the survey of Howard county afforded an opportunity to map the Iowan margin through a part of its course in this unknown territory. The work demonstrated the fact that along the northern state line the Kansan drift extends many miles farther east than does the Iowan, while at the middle of the north line of Delaware county the margins of the two till sheets appear practically to coincide. The correct mapping of the glacial deposits in northeastern Iowa can not be finished, however, until detailed surveys have been made in Clayton, Fayette and Winneshiek counties. In Howard county the Iowan boundary cuts the Minnesota line near the northwest corner of section 11, Forest City township, loops back into section 10 a few rods south of the line. trends almost south toward Foreston, turns southeastward and passes south of the mill at the village named, traverses the north half of section 14 and crosses into Albion township in the southwest quarter of section 18. From this point its course is in the main southeastward, passing a few rods south of the centers of sections 20 and 27, and leaving Albion township near the northeast corner of section 36. Here, as elsewhere, a thick loess ridge marks the limits attained by the Iowan ice. From the summit of this ridge one looks northward and northeastward over a succession of rounded, loess-covered hills which have been developed by long erosion of the older Kansan drift; toward the south and the southwest the Iowan drift plain, dotted with bowlders and free from loess, stretches away to the horizon, as level as a sea. The deeply eroded, weather-stained Kansan drift, with its mantle of loess, continues eastward, extending well across Winneshiek county, but the exact line which divides the drift-covered from the driftless area in this part of Iowa remains to be determined

when work has been extended over the unsurveyed counties through which the border of the old Kansan glaciers passes.

The subject of petroleum and natural gas continues to occupy a large share of public attention, a fact no doubt due to the phenomenal developments which have taken place at numerous points, particularly in Texas, Colorado and Wyoming. There have been a number of reported discoveries of petroleum in Iowa since the last annual report was written; and in some places the question of putting down prospect holes has been seriously considered. Oil and gas are two phases of the same phenomenon. They are likely to occur together, but occasionally one is found without the other. That they are both of organic origin is no longer seriously questioned; and if their organic origin is clearly apprehended, it will be unnecessary to state that they can occur only in formations that are younger than the introduction of life on the globe. The earliest faunas of any consequence lived during the Cambrian period; but it was not until the Trenton division of the next period that life existed in such profusion as to furnish organic matter in sufficient amount to give rise to gas or oil in quantities worthy of consideration. The Trenton, therefore, is the oldest formation in which oil or gas may be expected to exist in volumes of commercial importance; and as a matter of fact, it is the oldest in which these products have been found in paying quantities. So far as the presence of life is concerned, every formation since the Trenton might have become a source and reservoir of gas and oil; but the conservation and accumulation of these products of organic decay depend on a number of factors which must be coincident at the right time and place. For lack, therefore, of the requisite coincidence of favoring conditions, the formations are not all equally rich; and there is, furthermore, the largest possible variation in the matter of oil or gas content in different parts of the same formation. A very striking illustration of the truth of the last proposition is found in the fact that deposits of the Tertiary age are universally distributed over a large area in southern Texas. The thickness of the beds and their general characteristics are essentially the same everywhere in the region referred to, but oil production at Beaumont is limited to the small eminence known as Spindle Top,

which has an area of less than a square mile. The Trenton limestone is the productive formation in Indiana and western Ohio, but the production is limited to certain favored areas; while other areas in the same territory—in no way different so far as surface indications are concerned—are absolutely barren. The following table shows the geological distribution of gas and oil in the United States and Canada, and the distribution is essentially the same throughout the entire world:

TABLE SHOWING THE GEOLOGICAL DISTRIBUTION OF OIL AND GAS.

GEOLOGICAL PERIODS.	LOCALITIES.
Pleistocene or Quaternary.	No productive oil wells in deposits of this period. Small reservoirs of gas, in the form of sealed in beds of sand or gravel, occur in the glacial deposits at Letts, Herndon and a few other points in Iowa.
Tertiary....................	Los Angeles and other oil-producing localities in California; Beaumont, Texas; Jennings, Louisiana; some oil fields in Wyoming; oil fields in Russia and in Peru.
Cretaceous....................	Florence. Boulder and Pikes Peak, Colorado; San Antonia, Elgin and Corsicana, Texas; some oil horizons in Wyoming and British Columbia.
Jurassic....................	In one field in Wyoming oil occurs in the Jurassic. No productive wells, however, are yet known to be supplied from reservoirs belonging to this formation.
Triassic....................	No known oil-producing horizons in the Triassic.
Carboniferous.............	*Upper Carboniferous.* Popo Agie field, Wyoming; field in northern Indian Territory; Neodesha, Chanute, etc., Kansas. *Lower Carboniferous.* Central Ohio; West Virginia.
Devonian..................	Pennsylvania, western Ontario; some wells in central Ohio.
Silurian....................	No known productive wells, though oil occurs in the Medina sandstone in Canada, and the Niagara limestones about Chicago are, in places, saturated with oil. Some traces of oil at the same horizon in Cedar county, Iowa.
Ordovician..................	Oil and gas both abundant in certain localities, in the Trenton limestone, Gaspe, Canada; Lima and many other places in western Ohio; oil and gas fields in Indiana and Kentucky. Some Trenton shales in Iowa are rich in bitumen. In beds of Quebec age, Newfoundland.

GEOLOGICAL PERIODS.	LOCALITIES.
Cambrian........	No productive wells.
Algonkian.	No probability and little possibility of productive wells.
Erchæan......	No possibility of productive wells.

An examination of this table shows what has already been said, that the Trenton is the lowest of the geological formations yielding gas or oil in commercial quantities. Now the whole Trenton series crops out so that its several members may be studied as surface rocks in the northeastern counties of Iowa, and the Trenton underlies the surface at no very great depth in nearly all the other portions of the state. The demand for water has led to the boring of numerous deep wells for the purpose of drawing upon the supplies stored in the great water bearing sandstone, the Potsdam or Saint Croix, which lies at the base of the Paleozoic formations in the Mississippi valley. All wells in the interior of the state, which have reached the Cambrian sandstone, have passed through the whole thickness of the Trenton; and each well, so far as concerned the locality in which it was bored, was an effective test for gas or oil in the Trenton and in all the strata which lie above it. A few of the points where decisive tests have been made are Ackley, Amana, Anamosa, Ames, Boone, Burlington, Cedar Rapids, Centerville, Clinton, Davenport, Des Moines, Grinnell, Holstein, Homestead, Jefferson, Keokuk, Manchester, Mason City, Ottumwa, Pella, Sabula, Sigourney, Sioux City, Tipton, Vinton, Washington, Waverly, Webster City and West Liberty.

Another of the geological horizons of our state, in which organic matter is present in sufficient amount to make it a possible source of gas or oil, in the Upper Carboniferous. The gas and oil of southeastern Kansas are found in associated sandstones and shales of the same age as the Coal Measure deposits of Polk

county, Iowa. This possibly productive geological formation underlies the whole southwestern part of the state. In the southwestern counties, indeed, the geological conditions resemble very closely those at Neodesha and Iola, Kansas. The requisite conditions which have not yet been proven to exist are the porous reservoir and the proper cover; and these conditions might easily be met, even in such an undisturbed region as ours, by a large body of sandstone completely sealed in with shale. In general, productive fields are found in regions of disturbance where the sedimentary strata has been thrown into a series of folds. This is the situation in the productive belts of West Virginia, Pennsylvania, Ohio, Indiana, Colorado, Wyoming and in practically all other areas that could be mentioned. The oil bearing areas of Texas and Kansas may be exceptions, for here the reservoirs may be porous sands or sandstone, not folded, but thinning out at the edges so as to be completely shut in by impervious shales or clays. It is in such sealed-in reservoirs that gas occurs in the glacial deposits of Iowa and a few other localities in the drift-covered portions of North America.

The gas and oil belt of Indian Territory and Kansas is of especial interest to Iowans, for it has suggested to men of enterprise in certain localities the possibility of some as yet untapped reservoirs within the limits of our own state. This belt has a trend slightly east of north, and its extension would pass through northwestern Missouri into southwestern Iowa. Within the territory last named, however, the productive horizons of Kansas have been explored by the drill at such points as Atlantic, Centerville, Clarinda, Glenwood and Osceola, and in each case the results, so far as relate to oil and gas, have been negative. There is another thing to be kept in mind, and that is the fact that the Kansas belt becomes less productive toward the north. It seems as if the porous sandstones which constitute the reservoir thin out in this direction. Heavy bodies of sandstone in the lower Coal Measures, extending over areas of any considerable extent, have not been found in our state. These facts, it should be said, do not positively prove that there is no oil or gas in southwestern Iowa, but their bearing and significance will be readily appreciated by thoughtful and prudent investors. Every boring,

for whatever purpose made, which goes through the productive oil and gas horizons, simply limits by so much the area in which it is worth while even to think of spending money in prospecting.

In the report on Buchanan county, volume VIII, page 220, there is reference to a well defined fold which begins in Delaware county and, extending across Buchanan, passes into Bremer. This is one of the most marked and extensive folds affecting the geological strata of Iowa, and it might reasonably be expected that here, if anywhere, should be found conditions favorable to the accumulation and preservation of stores of gas and oil. So far this fold has not been fully explored by the drill; but the deep well at Waverly is not very far from its axis, and the Waverly well has gone down through all the possibly productive formations and deep into the Cambrian sandstones without bringing to light anything which could suggest even the presence of economic products other than a bountiful supply of pure, wholesome, artesian waters.

Letters received at this office, asking for information and advice relative to boring for oil or gas, have been more numerous during the past year than ever before. In every case the writers have been informed as to the exact facts and left to exercise their own judgment concerning the propriety of proceeding with the contemplated enterprise. In the matter of developing our natural resources the people of Iowa are entitled to the best information that geological science can give; and the present knowledge of the geological structure of the state makes it possible over the greater part of our area, to predict the outcome of drilling for water or for other products, with a high degree of accuracy. It is difficult, however, to get men—even the most intelligent of men—to appreciate the significance of some of the simplest of geological facts, when it happens that the men are not themselves geologists. Nevertheless the world is moving toward a brighter, higher and grander intelligence; and those whose mission it is to teach can afford to exercise patience, to labor and wait.

I have the honor to remain, gentlemen,

Yours very sincerely,

SAMUEL CALVIN.

REPORT OF ASSISTANT STATE GEOLOGIST.

STATE GEOLOGICAL SURVEY,
DES MOINES, December 31, 1901.

DEAR SIR:—I have the honor to submit the following report upon the work of the past year. During the winter and spring months a large share of my time was taken up with the duties connected with the publication of volume XI. These included the editing of the manuscripts, preparation of the maps and illustrations and reading the proof. The regular work of the office also included the answering of the numerous letters of inquiry which are constantly coming to the Survey. Information has been sought concerning the presence or absence in different portions of the state of coal, building stone, clay, artesian water and other mineral products. Not a few of these inquiries come from other states.

During the year the printing of Bulletin No. 1, on the Grasses of Iowa was also finished and the greater part of the edition has already been distributed. The demand has been large and the Bulletin has received wide and favorable mention.

In July, as soon as the completion of the printing allowed, I began field work in Wapello county and continued it with slight interruption until late in September. The area surveyed and mapped forms one of the important coal counties of the state, and its production of building stone and clay products is also large. Particular attention was given to the coal deposits of the region and to mapping the area covered by the Lower Carboniferous limestone, quarried so extensively as a building stone. Early in November a trip was made to Clarinda for the purpose of examining the core of a diamond drill hole sunk at that place several years ago. The record of this boring is an interesting and valuable one, since it is one of the few from the southwestern

part of the state and furnishes a knowledge of the character and thickness of the deeper strata. Much credit is due to the citizens of Clarinda, who have had the core carefully boxed and preserved. At the time the hole was sunk a record of it was kept by Mr. C. W. Stewart. This was kindly furnished the writer and was used for comparison with one made by the writer. For information respecting the existence of this drill core, as well as for many other similar favors, the Survey is indebted to Dr. Geo. L. Smith, of Shenandoah.

The following record was made from the examination and measurement of the core:

RECORD OF THE CLARINDA DIAMOND DRILL HOLE IN THE NORTHEAST PART OF TOWN. (Se. ¼ OF SEC. 29, TWP. 69 N., R. XXXVI W.)

		Thickness.	Depth.
109.	Drift	43	43
108.	Shale, blue	5	48
107.	Limestone	4	52
106.	Shale, black	1	53
105.	Coal	1¾	54¾
104.	Fire clay	2¼	57
103.	Shale, gray, calcareous and fossiliferous	17	74
102.	Shale, dark	2	76
101.	Limestone	2¾	78¾
100.	Shale, calcareous	1¼	80
99.	Limestone	6	86
98.	Shale, calcareous	1⅔	87⅔
97.	Limestone	3	90⅔
96.	Shale	6	96⅔
95.	Coal	⅓	97
94.	Limestone	18	115
93.	Shale	2	117
92.	Limestone	2	119
91.	Shale, dark, calcareous	2	121
90.	Limestone	2	123
89.	Shale, calcareous	15	138
88.	Limestone	4	142
87.	Shale, dark blue	36	178
86.	Limestone	7	185
85.	Shale, black	1	186
84.	Limestone	3	189
83.	Shale, black	12	201
82.	Limestone	7	208
81.	Shale, blue	1	209

		Thickness.	Depth.
80.	Limestone	2	211
79.	Shale, dark blue	8	219
78.	Limestone, carrying fusulinas	22	241
77.	Shale, dark blue	4	245
76.	Shale, calcareous	16	261
75.	Limestone	6	267
74.	Shale, calcareous	11	278
73.	Shale, red, green and blue	22	300
72.	Limestone	1	301
71.	Shale, dark blue	93	394
70.	Limestone	4	398
69.	Shale, dark blue, calcareous in part	15	413
68.	Limestone	16	429
67.	Shale, black and green	13	442
66.	Limestone	2	444
65.	Shale, black	16	460
64.	Limestone	1	461
63.	Shale, black	1	462
62.	Limestone	1	463
61.	Shale, green and black	6	469
60.	Coal	½	469½
59.	Shale, green and black	6½	476
58.	Limestone, impure, argillaceous	6	482
57.	Shale, black	13	495
56.	Limestone	1	496
55.	Shale, black	4	500
54.	Limestone	2	502
53.	Shale	3	505
52.	Limestone	19	524
51.	Shale, gray and black	4	528
50.	Limestone	1	529
49.	Shale	8	537
48.	Limestone, argillaceous	4	451
47.	Shale, green and black	5	546
46.	Limestone	10	556
45.	Shale, dark blue	16	572
44.	Limestone	4	576
43.	Shale, dark blue	2	578
42.	Limestone	22	600
41.	Shale, black and green	10	610
40.	Limestone	31	641
39.	Shale, black	8	649
38.	Limestone	2	651
37.	Shale	2	653
36.	Limestone	13	666
35.	Shale, black	3	669
34.	Coal	5-6	669 5-6

		Thickness.	Depth.
33.	Fire clay	2 1-6	672
32.	Limestone	9	681
31.	Shale	4	685
30.	Limestone	5	690
29.	Shale	13	703
28.	Limestone	6	709
27.	Shale	1	710
26.	Limestone	1	711
25.	Shale, gray	4	715
24,	Sandstone, micaceous	7	722
23.	Shale, sandy	25	747
22,	Sandstone	1	748
21.	Shale	5	753
20.	Coal	1	754
19.	Shale	1	755
18.	Limestone, argillaceous	3	758
17.	Shale	1	759
16.	Sandstone	4	763
15.	Shale, black	1	764
14,	Sandstone, sandy shale, fine, micaceous	19	783
13.	Shale	9	792
12.	Limestone	1	793
11.	Shale	4	797
10.	Limestone	6	803
9.	Shale	5	808
8.	Limestone	2	810
7.	Shale, black	3	813
6.	Coal	1/3	813 1/3
5.	Sandstone	7	820 1/3
4.	Limestone	5 2/3	826
3.	Shale	3	829
2.	Limestone	2	831
1.	Shale	9	840

The above differs materially from the record of the boring made southwest of Clarinda, in the southwest quarter of section 36, and given in Professor Calvin's report on Page county. But the latter hole was made with a churn drill and the samples of the drillings were never examined by a member of the Survey. The limestones and shales alternate so rapidly and graduate the one into the other in such a way as to make their discrimination difficult, especially in the drillings. Entire confidence cannot therefore be placed in the record already published and it is believed that the one given above is much more accurate. When

the core can be examined the character and thickness of the different strata can be determined with greater reliability. This one resembles the Glenwood section in the rapid alternation of shales and limestones and in the large number of limestone layers. At Glenwood there are sixteen limestone horizons in that portion of the section referred to the Missourian and at Clarinda there are thirteen.

The upper coal seam, No. 105, is mined in several places near town, two mines having been opened in it during the past year (1901). This seam is the Nodaway coal, which is mined at several points in Page and surrounding counties.

In the above section the base of the Missourian is believed to be at about 715 feet, there being but little limestone below that depth. This would give the Missourian here a thickness of 670 feet, which is the thickness given for that formation at Glenwood.

During the past year the following publications have been added to the library of the Survey:

Annual Report of Smithsonian Institution, 1900.
Annals of the New York Academy of Sciences, Vol. XII, Parts II and III, Vol. XIII. Part I.
Proceedings of the United States National Museum, Vols 22 and 23.
Geological Survey of Alabama. Plant Life of Alabama.
25th Annual Report of Indiana Geological Survey.
Maryland Geological Survey. Eocene.
Geological and Natural History Survey of Minnesota, Vol. 6 Atlas.
Transactions of the Kansas Academy of Science, Vol XVII.
Bulletin of the Buffalo Society of Natural Sciences, Vol. VII, No. 1.
Proceedings and Collections of the Wyoming Historical and Geological Society for 1900.
Geological Survey of New South Wales. The Mineral Resources of New South Wales.
Proceedings of the Philosophical Society of Glasgow, Vol. XXXII.
Report of the Ontario Bureau of Mines.
Eclogæ Geologicæ, Helvetæ, Vol. V.

Very Respectfully,
A. G. LEONARD,
Assistant State Geologist.

TO PROF. SAMUEL CALVIN,
State Geologist.

REPORT OF PROF. W. H. NORTON, IN CHARGE OF ARTESIAN WELLS.

Dr. Samuel Calvin, Director, Iowa Geological Survey:

SIR:—I have the honor to make the following report of the work done during the year 1901 in reference to the artesian wells of the state.

During the past year a smaller number of wells was being drilled within the limits of the state than in several previous years, and the opportunities of this office have been correspondingly diminished.

We have advised with the State Board of Control as to a number of wells now drilling or in contemplation at state institutions. Of the well at Mitchellville, we were kept informed as the drilling progressed, and were thus able to state the formations in which the drill was working, and the probabilities as to their water supply.

The unfinished well at the Hospital for the Insane at Cherokee has also been placed under our advisory supervision. A complete set of samples of the drillings has been sent to the office of the 1,000 feet already drilled, and others will be forwarded as the work goes on. While at present advising the further prosecution of the boring, we shall be able to advise against its continuance, whenever we find that it has passed below the water bearing strata, or aquifers of the region, thus making it possible to avoid the waste of thousands of dollars which in a number of cases in Iowa as well as in other states, has resulted from drilling wells to needless depths for want of expert advice. The drillings from the Cherokee well will give us for the first time a reliable lithological section of the deeper rocks in this region of the state, and data of great value in regard to its water resources.

We were also consulted by the Board of Control as to the advisability of sinking new wells at the state institutions at Glenwood and Mt. Pleasant, in proximity to the deep wells there, whose

capacity is not equal to the needs of the hospitals; and in each case were able to give favorable reply, after taking into account the various factors in the cases.

To the chief engineer of the Minneapolis and St. Louis Railway, we were able to supply a large amount of data as to the extent and depth of the leading water horizons of those portions of the state traversed by that railway.

The deep well at Sumner, over which we had some supervision, has been brought to a satisfactory completion, after a series of delays owing to accidents of the usual kinds in the progress of the work. Through the intelligent care of the council, a complete set of drillings was preserved, most of which have already been sent to this office.

The Board of Control has also directed that the sample drillings from the artesian well recently drilled at the Hospital at Mt. Pleasant be sent here for determination. This will give a reliable geographical section for this area, where our data had before this been incomplete.

We have collected data of considerable value from a number of wells recently sunk, from the second and third wells of the waterworks at Boone, from the well at the state institution at Glenwood, and from the Davenport artesian field relating to interference of wells.

I have the honor to remain your obedient servant,

WILLIAM HARMON NORTON.

Cornell College, Mt. Vernon, Iowa, Jan. 17, 1902.

REPORT OF DR. J. B. WEEMS.

AMES, IOWA, December 31, 1901.

SIR:—I have the honor of presenting the following report for the Chemical Work of the Geological Survey.

The laboratory work has been limited to the analysis of clays in connection with the investigation of the clays of the state.

During the year twenty-five samples of clay have been analyzed. The analytical work included complete chemical and rational analyses for each sample. The Chemical Section of the Experiment Station is continuing its work upon the soils furnished by the Survey.

The lack of space for the chemical work of the department and the Chemical Section of the Station has made the work for the Survey a difficult matter, and has caused long delays in the chemical work.

The Grass Bulletin prepared by the Departments of Botany and Agricultural Chemistry of the College has been completed and published during the year. The work has been well received by those interested in the advancement of agriculture.

Respectfully submitted,

J. B. WEEMS,

Chemist.

TO PROF. SAMUEL CALVIN,

State Geologist.

MINERAL PRODUCTION OF IOWA

IN 1901

BY

S. W. BEYER.

VALUE OF MINERAL PRODUCTION.

1900.

Coal	$6,977,466
Clay	2,395,488
Stone	604,886
Gypsum	393,750
Lead and zinc	22,194
Iron ore	2,139
Total	$10,401,661

1901.

Coal	$8,051,806
Clay	2,774,200
Stone	781,756
Gypsum	562,500
Lead and zinc	16,500
Iron ore	4,876
Total	$12,204,160

MINERAL PRODUCTION IN IOWA FOR 1901.

BY S. W. BEYER.

The year 1901 shows a splendid increase in mineral production for Iowa over preceding years, both in quantity and price. This increase is not confined to any one department but every department save that of lead and zinc shared in the prosperity. Coal alone shows an advance in total value of over a million of dollars or a net increase of about fifteen per cent. Clay shows almost the same percentage of increase, while the value of stone advanced thirty per cent and the iron ore production more than doubled. The statistics for gypsum were not complete for 1900 and comparisons cannot be made in detail. The output for 1901, however, shows a fair increase over 1900. The total number of producers increased about five per cent, chiefly due to the more complete returns from the stone producers.

The number of producers in the various mineral industries of the state may be viewed in parallel columns for the years 1900 and 1901 in the table below.

	1900.	1901.
Coal	231	242
Clay	381	349
Stone	170	229
Gypsum	7	7
Lead and zinc	6	10
Iron ore	1	1
Total	796	838

As during the preceding years the gathering of mineral statistics was carried on jointly by the State and Federal Surveys. The original requests were sent out from Washington, while the task of looking up the delinquents devolved largely upon the local office.

Full acknowledgment is due the producers for the promptness shown by the great majority in answering the communications sent them and for the painstaking completeness of their reports.

The value of the total mineral production is shown in table I

TABLE I.

VALUE OF TOTAL MINERAL PRODUCTION BY COUNTIES.

COUNTIES.	Number of Producers.	Total coal.	Total clay.	Total stone	Miscel- laneous.	Total.
Adair	4		$ 8,700			$ 8,700
Adams	17	$ 28,113	13,350	$ 875		42,338
Allamakee	4			11,425	$ 4,876	16,301
Appanoose	54	1,336,662	17,650	163		1,344,475
Audubon	2		13,950			13,950
Benton	9		16,528	7,830		24,358
Black Hawk	13		15,495	11,651		27,146
Boone	21	421,179	50,275			471,454
Bremer	3		5,061			5,061
Buena Vista	2		22,467			22,467
Buchanan	1					
Butler	1					
Calhoun	4		19,925			19,925
Carroll	1					
Cass	5		14,412			14,412
Cedar	4			71,720		71,720
Cerro Gordo	10		162,225	19,250		181,475
Cherokee	1					
Chickasaw	1					
Clarke	5			1,457		1,459
Clayton	13		11,626	11,463		23,088
Clinton	16		14,400	7,877		22,277
Crawford	2		10,720			10,720
Dallas	10	30,524	63,660	150		94,334
Davis	4	2,357	1,597			3,954
Decatur	9		7,237	1,593		8,830
Delaware	3		5,100	30		5,130
Des Moines	16		29,030	25,417		54,447
Dubuque	24		34,150	69,058	16,500	119,708
Fayette	7		16,020	4,800		20,820
Floyd	5		3,989	5,150		9,139
Fremont	6		13,300			13,300
Franklin	1					
Greene	6	29,893				29,893
Grundy	2			640		640
Guthrie	5		30,606			30,606
Hamilton	5		75,910	1,800		77,710
Hancock	1					
Hardin	10		47,970	13,105		61,075
Harrison	7		16,200			16,200
Henry	8		15,330	14,650		29,980
Howard	4			1,981		1,981
Humboldt	3			1,520		1,520
Ida	1					
Iowa	4		29,612			29,612
Jackson	5			162,205		162,205
Jasper	16	267,393	27,150			294,543
Jefferson	7	2,748	17,846	125		20,719
Johnson	7		25,600	3,480		29,080
Jones	10		7,300	96,171		103,471
Keokuk	32	527,527	30,215	3,548		561,290

TABLE I—CONTINUED.

VALUE OF TOTAL MINERAL PRODUCTION BY COUNTIES.

COUNTIES.	Number of Producers.	Total coal.	Total clay.	Total stone.	Miscel-laneous.	Total.
Kossuth	1					
Lee	25		$ 13,339	$54,005		$ 67,344
Linn	17		43,428	23,133		66,561
Louisa	13		8,700	3,907		12,607
Lucas	2	$ 266,916				266,916
Madison	11			16,508		16,508
Mahaska	35	1,332,691	73,132	1,305		1,407,128
Marion	21	185,744	12,715			198,459
Marshall	9		36,450	47,900		84,350
Mills	3		18,200			18,200
Mitchell	2			4,093		4,093
Monona	2		2,665			2,665
Monroe	12	1,480,917	912	457		1,482,286
Montgomery	6		39,190	1,182		40,372
Muscatine	8		28,270			28,270
O'Brien	2		3,035			3,035
Page	5	17,050	32,700			49,750
Plymouth	2		6,600			6,600
Pocahontas	1					
Polk	41	1,378,125	426,978			1,805,103
Pottawattamie	9		71,350			71,350
Poweshiek	4		15,940			15,940
Ringgold	3		14,038			14,038
Sac						
Scott	23	22,303	57,450	56,992		136,745
Shelby	4		13,360			13,360
Sioux	2		9,875			9,875
Story	6	900	30,193			31,093
Tama	8		63,500	325		63,825
Taylor	7	50,098	13,492			63,590
Union	2		16,860			16,860
Van Buren	11	18,993	5,375	395		24,763
Wapello	24	325,653	64,093	14,757		404,503
Warren	8	56,858				56,858
Washington	14		29,175	12,404		41,579
Wayne	7	32,544	10,390	41		42,975
Webster	36	236,618	201,075	9,475	$562,500	1,009,668
Winneshiek	2		4,950			4,950
Woodbury	6		227,154			227,154
Wright	3		6,372			6,372
Single producers			132,241	5,458		137,699
Unclassified	16		146,900			146,900
Total	838	$8,051,806	$2,774,200	$781,756	$583,876	$ 12,204,160

COAL.

The price of coal was strong and on the advance during the entire year. This advance in price was in part due to the increased cost of mining owing to the wage scale adopted by the joint committee or scale committee of the miners and operators of the district, generally known as the "Ottumwa Agreement," and effective between April 1, 1901, and March 31, 1902. This agreement was also responsible in large part for the increase in the number of men employed. Table II shows that while the tonnage production increased only about ten per cent the number of employes increased almost twenty per cent. The "Ottumwa Agreement" established the eight-hour day and hence the change in number of men employed. The average price per ton advanced five cents, or a little less than four per cent over the preceding year.

During the year work in exploration was pushed vigorously in Monroe, Polk and Marion counties. No less than twelve drill rigs were operating in Monroe county alone. Good results were reported from all of these counties and important developments may be expected in the near future, particularly in the first two counties mentioned.

Table II gives the total tonnage, average price per ton, total value, number of mines producing, average number of days worked and number of men employed, arranged by counties. No attempt was made to keep separately the various sizes of coal put upon the market. Mine run, steam coal, nut and slack are included in the total. This fact must be kept in mind if an analysis by counties be attempted. The Centerville and Boone districts mine "longwall" largely and produce almost no slack and the average price per ton given would be for lump coal, while the districts which "shoot from the solid" produce at least thirty per cent fine coal sold as "steam," "nut," "pea" or "slack." The statistics are also incomplete as to distribution. A considerable number of the coal companies do not keep a separate record for coal sold to employes or locally and the great majority keep no record of the amount consumed at the mines; at least few return amounts so consumed. The amounts shipped or sold locally vary greatly for the different coal producing counties. In Adams

county the mines are small and the entire output is sold locally, while in Monroe county the large railway mines prevail and scarcely more than one per cent is consumed at home. In Appanoose county between five and six per cent of the output is sold at home while in Polk where the urban population is greatest the home consumption exceeds twenty-five per cent. The first two counties represent the extremes in the distribution of the coal output while the two last mentioned counties more nearly represent the average for country and city districts respectively. The average for the entire state, barring coal used for steam and heat at the mines, would be not far from fifteen per cent sold at home to eighty-five per cent shipped.

TABLE II.

COAL OUTPUT BY COUNTIES FOR 1901.

COUNTIES.	Number of mines.	Tonnage.	Value.	Average price per ton.	Aver'ge number men employed.	Aver'ge number days worked.
Adams	12	12,953	$ 28,113	$ 2.17	98	147
Appanoose	47	868,967	1,336,662	1.54	2,566	196
Boone	11	257,033	421,179	1.64	791	215
Dallas	3	16,988	30,524	1.79	56	182
Davis	2	1,364	2,357	1.73	18	92
Greene	5	16,450	29,893	1.82	60	154
Jasper	8	183,500	267,393	1.45	375	239
Jeffeeson	2	1,248	2,748	2.20	6	145
Keokuk	11	366,915	527,527	1.44	989	234
Lucas	2	216,058	266,916	1.23	417	210
Mahaska	29	899,618	1,332,691	1.49	1,695	215
Marion	17	149,917	185,744	1.24	371	188
Monroe	8	1,237,332	1,480,917	1.20	2,515	275
Page	3	6,820	17,050	2.50	20	248
Polk	23	954,112	1,378,125	1.44	1,914	225
Scott	7	13,857	22,303	1.61	72	190
Story	1	300	900	3.00	6	75
Taylor	3	23,499	50,098	2.13	[illegible]	232
Van Buren	5	12,572	18,993	1.51	37	182
Wapello	14	249,880	325,653	1.31	529	227
Warren	8	26,261	56,858	2.17	108	147
Wayne	2	19,478	32,544	1.67	71	197
Webster	19	127,894	236,618	1.85	238	228
Total	242	5,663,016	$ 8,051,806	$ 1.42	13,032	223

The average number of days worked shows a falling off in Keokuk, Lucas, Mahaska, Marion and Wapello counties; a falling

off great enough to affect the entire state, notwithstanding the marked increase in the number of days worked in Monroe county. The average number of days worked and the number of men employed during the past ten years, according to the best information available, was as follows:

YEARS.	AVERAGE NUMBER OF DAYS WORKED.	NUMBER OF MEN EMPLOYED.
1892	236	8,170
1893	204	8,863
1894	170	9,995
1895	189	10,066
1896	178	9,072
1897	201	10,703
1898	218	10,250
1899	220	10,268
1900	228	11,001
1901	223	13,032

According to the authority of the United States Geological Survey, Iowa ranked ninth in tonnage and sixth in the value of coal produced for 1900. The ten leading producers for that year tabulated in the order of their importance as to tonnage were:

	TONS.	VALUE.
Pennsylvania (bituminous only)	79,842,326	$ 77,438,545
Illinois	25,767,981	26,927,185
West Virginia	22,647,207	18,416,871
Ohio	18,988,150	19,292,246
Alabama	8,394,275	9,793,785
Indiana	6,484,086	6,687,137
Kentucky	5,328,964	4,881,577
Colorado	5,244,364	5,858,036
Iowa	5,105,[illegible]51	6,977,466
Kansas	4,467,870	5,454,691

Iowa's increase in production over preceding years is made more manifest by an inspection of the comparative table below:

YEARS.	SHORT TONS.	AVERAGE PRICE PER TON.	VALUE.	AUTHORITY.
1894	3,967,253	$1.26	4,999,939	U. S. G. S.
1895	4,156,074	1.20	4,982,102	U. S. G. S.
1896	3,954,028	1.17	4,628,022	U. S. G. S.
1897	4,611,865	1.13	5,219,503	U. S. G. S.
1898	4,618,842	1.14	5,268,716	U. S. G. S.
1899	5,177,479	1.24	6,399,338	U. S. G. S.
1900	5,165,151	1.37	6,977,466	Iowa Geol. Sur.
1901	5,[illegible],016	1.42	8,051,806	Iowa Geol. Sur.

According to the Tenth Biennial Report of the State Mine Inspectors the output of coal for the year ending June 30, 1901, was 5,441,863 tons.

CLAY.

The clay production for 1901 was the greatest in the history of the state. There was an increase in both price and production. The returns show a falling off in the number of producers, chiefly small concerns using the loess and other surface clays. Several large factories were opened during the year, notably at Boone and Lehigh, and several others have made the necessary preparations to begin active operations in 1902, the most important of which are located at Des Moines, Iowa Falls and Marshalltown. As yet but feeble attempts have been made to manufacture high grade and ornamental wares. The chief staples are common brick and tile, face brick and paving brick. The pottery production shows a falling off of more than forty per cent over the preceding year. The increase in paving brick both in price and number manufactured is gratifying and warrants the hope that Iowa may again regain her importance as a producer in that line. The clay goods marketed during 1901 were distributed as follows:

	THOUSANDS.	VALUE.
Common Brick	254,432	$ 1,651,926
Front Brick	8,577	85,330
Paving Brick	22,530	227,378
Hollow Brick	400	3,000
Ornamental Brick		2,229
Fire Brick		803
Drain Tile		516,714
Sewer Pipe		53,500
Sidewalk Blocks		1,570
Hollow Blocks		59,270
Burnt Clay Ballast		101.500
Pottery		26,200
Miscellaneous		14,780
Total		$ 2,774,200

The most important increase of 1901 over 1900 was in the manufacture of drain tile, an increase of nearly thirty-five per cent in value. The increase in this department is even a better

index of the prosperous condition of the rural population than is the increase in the production of common brick and paving brick, a measure of the thriftiness of the urban communities. The price of common brick did not change materially as compared with the preceding year, the average being about $6.49 per thousand as compared with $6.47 for 1900. Nearly all of the other products increased in price and the amount produced. Clay ballast dropped from nearly $200,000 to scarcely more than half the amount. Hollow building blocks are rapidly gaining favor both with producer and consumer. They can be manufactured more cheaply than ordinary brick, can be shipped greater distances at the same expense and are more economical to put in the wall, aside from possessing certain sanitary advantages. The outlook in this field is especially inviting.

The distribution of clay products by counties is contained in table III, herewith appended:

TABLE III.

CLAY PRODUCTION BY COUNTIES FOR 1901.

COUNTIES.	Number of producers.	THOUSANDS.		VALUE.		
		Common brick.	*Total brick.	Common brick.	Total brick.	Total clay.
Adair	4	1,250	1,300	$ 8,000	$ 8,500	$ 8,700
Adams	4	1,951	1,951	13,050	13,050	13,350
Appanoose	4	1,875	2,375	12,650	17,650	17,650
Audubon	2	1,950	1,950	13,650	13,650	13,950
Benton	5	1,675	1,775	10,638	11,638	16,528
Black Hawk	3	2,432	2,432	15,495	15,495	15,495
Boone	10	4,904	5,854	35,050	44,675	50,275
Bremer	3	723	723	5,061	5,061	5,061
Buena Vista	3	550	550	4,400	4,400	22,467
Buchanan	1	....	....	....	....	....
Butler	1	....	....	....	....	....
Calhoun	4	1,075	1,075	5,925	5,925	19,925
Carroll	1	....	....	....	....	....
Cass	5	2,039	2,039	14,412	14,412	14,412
Cedar	1	....	....	....	....	....
Cerro Gordo	3	6,647	6,647	39,982	39,982	162,225
Chickasaw	1	....	....	....	....	....
Cherokee	1	....	....	....	....	....
Clarke	1	....	....	....	....	....
Clayton	5	1,960	1,962	11,080	11,116	11,626
Clinton	4	1,950	1,950	11,200	11,200	14,400
Crawford	2	1,400	1,420	10,500	10,720	10,720
Dallas	6	3,277	4,270	22,128	33,142	63,660

*Not including fire and ornamental brick.

TABLE III—CONTINUED.

CLAY PRODUCTION BY COUNTIES FOR 1901.

COUNTIES.	Number of producers.	THOUSANDS. Common brick.	THOUSANDS. *Total brick.	VALUE. Common brick.	VALUE. Total brick.	VALUE. Total clay.
Davis	2	222	222	$ 1,597	$ 1,597	$ 1,597
Decatur	4	1,055	1,055	6,737	6,737	7,237
Delaware	2	700	775	4,500	5,100	5,100
Des Moines	5	2,640	3,865	14,800	26,030	29,030
Dubuque	4	5,800	5,800	34,150	34,150	34,150
Fayette	4	1,765	2,265	11,220	15,220	16,020
Fremont	6	2,310	2,310	13,300	13,300	13,300
Floyd	2	527	527	3,989	3,989	3,989
Franklin	1	....	....	....	....	....
Greene	1	....	....	....	....	....
Grundy	1	....	....	....	....	....
Guthrie	5	2,141	2,191	15,792	16,192	30,606
Hamilton	3	5,120	5,120	35,910	35,910	75,910
Hardin	5	820	820	5,220	5,220	47,970
Harrison	7	2,585	2,585	16,200	16,200	16,200
Henry	5	870	1,070	5,520	6,930	15,330
Howard	1	....	....	....	....	....
Humboldt	1	....	....	....	....	....
Ida	1	....	....	....	....	....
Iowa	4	3,375	3,375	20,862	20,862	29,612
Jasper	8	3,600	3,700	22,450	23,300	27,150
Jefferson	4	1,112	1,112	7,896	7,896	17,846
Johnson	5	2,250	3,050	13,500	18,300	25,600
Jones	2	540	690	3,825	4,025	7,300
Keokuk	8	1,790	1,795	11,860	11,965	30,215
Kossuth	1	....	....	....	....	....
Lee	5	2,175	2,225	12,680	13,089	13,339
Linn	10	5,950	5,970	37,108	37,248	43,428
Louisa	5	1,140	1,140	7,700	7,700	8,700
Madison	1	....	....	....	....	....
Mahaska	5	4,657	7,857	33,932	66,332	73,132
Marion	4	1,515	1,615	9,755	10,755	12,715
Marshall	6	3,775	4,025	23,200	25,200	36,450
Mills	4	2,600	2,600	18,200	18,200	18,200
Monona	2	370	370	2,665	2,665	2,665
Monroe	2	127	127	912	912	912
Montgomery	4	5,490	5,490	38,430	38,630	39,190
Muscatine	8	4,675	4,675	27,950	27,950	28,270
O'Brien	2	550	550	3,000	3,000	3,035
Page	3	5,675	5,675	32,700	32,700	32,700
Plymouth	2	1,100	1,100	6,600	6,600	6,600
Pocahontas	1	....	....	....	....	....
Polk	18	30,923	42,923	214,878	345,778	426,978
Pottawattamie	9	11,000	11,700	66,425	71,225	71,350
Poweshiek	4	1,280	1,280	8,940	8,940	15,940
Ringgold	3	2,200	2,200	14,038	14,038	14,038
Sac	1	....	....	....	....	....
Scott	6	8,700	8,700	53,150	53,150	57,450
Shelby	4	1,930	1,930	13,150	13,150	13,360

*Not including fire and ornamental brick.

TABLE III—CONTINUED.

CLAY PRODUCTION BY COUNTIES FOR 1901.

COUNTIES.	Number of producers.	THOUSANDS.		VALUE.		
		Common brick.	*Total brick.	Common brick.	Total brick.	Total clay.
Sioux	2	1,425	1,425	$ 9,875	$ 9,875	$ 9,875
Story	5	1,408	1,658	11,354	13,097	30,193
Tama	6	4,800	6,800	31,000	50,500	63,500
Taylor	4	1,382	1,990	13,112	13,192	13,192
Union	2	2,330	2,330	16,310	16,310	16,860
Van Buren	4	675	675	4,375	4,375	5,375
Wapello	4	8,491	9,736	52,874	62,743	64,093
Washington	6	3,971	3,971	23,875	23,875	29,175
Wayne	5	1,515	51,545	10,390	10,390	10,390
Webster	7	14,600	18,700	88,675	130,475	201,075
Winneshiek	2	900	900	4,950	4,950	4,950
Woodbury	6	31,532	33,2[illegible]1	204,840	219,154	227,154
Wright	3	75	75	675	675	6,372
Single producers (16)		8,616	8,616	56,259	56,259	132,241
Burnt clay ballast	2	....	....	....	....	101,501
Pottery	7	....	....	....	....	26,200
Estimates	6	1,500	1,500	10,500	10,500	19,500
Total	349	254,432	286,039	$ 1,651,926	$ 1,970,666	$2,774,200

*Not including fire and ornamental brick.

During the three years preceding 1901 Iowa ranked eighth as a clay producer and doubtless has held her own for the year just closed. In 1898 she ranked fourth as a producer of vitrified brick for paving, in 1899 she dropped to seventh place while in 1900 she was a poor ninth. Paving brick have shown a remarkable advance in price per thousand during the last three years. The prices being $6.81, $8.73 and $70.09 respectively for the years 1899, 1900 and 1901.

The table appended herewith gives the ten leading clay producers for 1900 according to the figures contained in the Mineral Resources for 1900.

RANK.	STATE.	OPERATORS REPORTING.	VALUE.	PER CENT TOTAL PRODUCT FOR U. S.
1	Ohio	871	$ 18,304,628	19 03
2	Pennsylvania	508	13,391,748	13.92
3	New Jersey	149	10 928 423	11 36
4	Illinois	569	7 708,859	8 01
5	New York	269	7 660 606	7.96
6	Indiana	567	3 858 350	4.01
7	Missouri	267	3 736 567	3.88
8	Iowa	358	2 291 251	2 38
9	West Virginia	53	2 016 765	2.10
10	Massachusetts	101	1 833 101	1.91

STONE.

Nearly all of the stone producers report a stronger demand for stone for 1901 than for the preceding year. The figures returned bear out their statements and the output is $796,852 for 1901 against $604,886 for the year 1900.

The production was distributed as follows:

Limestone used for—	
Building purposes	$261,160
Flagging and curbing	18,095
Rip-rap, rubble, etc	66,355
Made into lime	230,188
Crushed stone for—	
Road making (Macadam, etc.)	68,580
Railroad ballast	48,509
Concrete, etc.	75,182
Bridge stone	9,809
Blast furnace flux	250
Other purposes	5,328
Sandstone	13,096
Total	$796,852

The production of lime more than doubled that of 1900. The classification of products is more in detail than heretofore observed and it is scarcely possible to make comparisons of the individual items. Table IV gives the production by counties and specifies the various grades of stone put upon the market.

TABLE IV.

PRODUCTION OF LIMESTONE BY COUNTIES FOR 1901.

Number of producers.	COUNTIES.	Building.	Flagging and curbing.	Rip-rap and rubble.	Lime.	Road making.	Railway ballast.	Concrete.	Other purposes.	Total.
1	Adams	$ 625		$ 250						$ 875
3	Allamakee	9,925	$ 1,000	250					$ 250	11,425
3	Appanoose	105	58							163
4	Benton	1,361	59	10	$ 6,400					7,830
12	Black Hawk	9,796	237	50	1,500			$ 40		11,623
4	Clarke	1,150	232	75						1,457
7	Cerro Gordo	11,525	450	1,975	5,100			200		19,250
7	Clayton	5,300	1,400	1,500	2,875					11,075
3	Cedar	8,750		430	11,800	$44,820	$ 5,920			71,720
10	Clinton	2,689	8	3,688		803				7,188
1	Dallas	150								150
1	Delaware	30								30
5	Decatur	968	182	143		100	200			1,593
11	Des Moines	13,691	484	2,861	125	1,105		7,126	2,025	25,417
11	Dubuque	39,819	1,512	5,216	15,280	1,149	300	1,780		67,056
2	Fayette	500			4,225					4,725
3	Floyd	4,550	500						100	5,150
1	Grundy	640								640
2	Hamilton	1,800								1,800
5	Hardin	11,780	525	600	200					13,105
3	Henry	7,900	150			2,500		4,000	100	14,650
3	Howard	1,760	21	200						1,981
2	Humboldt	1,500	20							1,520
5	Jackson	325		200	161,480	200				162,205
2	Johnson	2,800				400		280		3,480
8	Jones	40,203	1,436	11,677		2,569	30,389	4,997	4,900	96,171
11	Keokuk	3,037	60	51		150				3,298
17	Lee	14,567	124	1,650	11,153	4,293		21,619	15	53,421
7	Linn	3,368		1,015	9,000	750		9,000	309	23,133

TABLE IV—CONTINUED.

PRODUCTION OF LIMESTONE BY COUNTIES FOR 1901.

Number of producers	COUNTIES.	Building.	Flagging and curbing.	Rip-rap and rubble.	Lime.	Road making.	Railway ballast.	Concrete.	Other purposes.	Total.
8	Louisa	$ 3,448	$ 150							$ 3,907
10	Madison	9,279	24	$ 712		$ 923		$ 5,570		16,508
3	Marshall	2,000	9,200	24,250			$11,700	750		47,900
3	Mahaska	505		200						705
2	Mitchell	993		100	$ 900	2,100				4,093
2	Monroe	429	28							457
2	Montgomery	1,182								1,182
10	Scott	24,297	25	6,602	150	6,418		19,500		56,992
2	Tama	325								325
2	Van Buren	75						320		395
6	Wapello	13,072	85	1,600						14,757
8	Washington	3,241	125	1,050		300			$ 7,688	12,404
	Single producers	3,445		250						3,695
213		$ 261,460	$18,095	$66,355	$ 230,188	$68,680	$48,409	$75,182	$ 5,328	$781,756

SANDSTONE PRODUCTION FOR 1901.

COUNTIES	Number of producers.	Building.	Rubble, rip-rap, etc.	Total.
Black Hawk	1	$ 14	$ 14	$ 28
Clayton	1	210	178	388
Clinton	2	454	235	689
Fayette	1	75	....	75
Hancock	1	....	308	308
Jefferson	1	125	....	125
Keokuk	2	240	10	250
Lee	3	332	252	584
Mahaska	1	600	....	600
Webster	3	9,450	25	9,475
Total	16	$ 11,500	$ 1,022	$ 12,522

In 1900 Iowa ranked twenty-first among the stone producers and ninth as a producer of limestone. The production of the state for the last ten years is given in the table herewith appended:

YEAR.	Sandstone.	Limestone.	Total.
1892	$ 25,000	$ 705,000	$ 730,000
1893	18,347	547,000	565,347
1894	11,639	616,630	628,269
1895	5,575	449,501	455,076
1896	12,351	410,037	422,388
1897	14,771	480,572	495,343
1898	6,562	557,024	563,586
1899	17,239	792,685	809,924
1900	9,379	595,507	604,886
1901	13,096	783,756	796,852

GYPSUM.

The year 1901 proved to be a record breaker in the plaster industry of the Fort Dodge district. As during the preceding year seven companies were in operation. During a portion of the year competition between the various companies in operation was very sharp and the price fell as low as $3.50 per ton for retarded plaster, f. o. b. Fort Dodge. Later in the season the companies succeeded in adjusting their differences, and the price went back to about

$5 per ton. Appoximately seventy-five per cent of the product left the mills in the form of retarded plaster for plaster purposes, while the major portion of the balance left in the form of unretarded calcined plaster, a considerable portion of which goes to the mixers who subsequently mix it with retarder and sand for plastering purposes. A small per cent of the whole is used without retarder for hard coat and plaster of Paris finish. Doubtless less than one per cent of the whole product produced at Fort Dodge is used for other mechanical purposes than plastering. None of the gypsum is shipped for treatment elsewhere. A small portion is used as a base in the manufacture of paint by the Fort Dodge Paint Manufacturing Company, but will not affect the total. The best information at hand would make the production for 1901 125,000 tons, sold at an average of $4.50 per ton f. o. b. Fort Dodge, giving a total value of $562,500.

LEAD AND ZINC.

The production of zinc in the Dubuque region has been reduced to inconsiderable proportions. This has been brought about largely by the sharp decline in the price of zinc, and to a less extent through the exhaustion of the ore bodies in sight. The weak demand and low price have held out no inducements toward the active prospecting and development of new properties as in the years 1898 and 1899. Ore was sold during the year at a price which would not cover the cost of production, let alone yielding a reasonable return to the operator. The entire output for the Iowa field scarcely reached 350 tons, principally carbonate, "dry bone," and sold at an average of $7.70 per ton. The most select stock sold for $12 per ton, yielding fair returns to the labor and capital employed, while certain low grade ores were disposed of at $5 per ton, entailing a considerable loss to those concerned. Almost the entire output was shipped to Mineral Point, Wisconsin. LaSalle, Illinois, may be considered as a competing market, but rarely affords active competition. The two largest companies remained practically closed or were only worked in a desultory way on account of legal complications.

The Alpine Zinc Company has abandoned their old workings, at least temporarily, on account of water, but have sunk a new

shaft on the same vein several hundred yards to the westward, which promises well. A good body of high grade ore is in sight and will be marketed as soon as the price warrants.

The zinc industry in the Dubuque region gives little promise for the future unless prices strengthen materially. The plant of the Dubuque Ore Concentrating Company lay idle during the year because of the intermittent and insufficient supply of crude ore and the general decadence of the industry.

The falling off in the demand for zinc has not materially affected the demand for lead. Most of the energy and capital formerly occupied in the development of zinc properties is now devoted to the opening of lead properties. Prospecting has been vigorously prosecuted during the past year, and several rich bodies of "mineral" have been brought to light. The demand ruled firm and the price steady throughout the year and those employed in the production of lead ore were able to secure good returns for their labor and capital. Practically all the ore produced was galena and all of it was sold to the local smelter, owned and operated by Wm. G. Watters of Dubuque. The ore smelted during the year amounted to a million and a half pounds, purchased at an average price of $23 per thousand pounds and cleaning up an average of 72 per cent lead.

The production of zinc and lead for Iowa may be recapitulated briefly as follows:

Zinc, 350 tons	$ 2,500
Lead, 600,000 lbs	13,800
	$16,300

Lead smelted by Wm. G. Watters' smelter was contributed by the following states:

	POUNDS.	VALUED AT.
Iowa	600,000	$13,800
Illinois	700,000	16,100
Wisconsin	200,000	4,600
Total	1,500,000	$34,500

IRON ORE.

Since 1899 Iowa has consistently held her position in the column of iron ore producers. In 1899 the output was 1,250 long

tons, which was almost quadrupled for 1901. In view of the extensive improvements recently made for mining and handling the ore the opportunity is taken of dealing with the subject in some detail. Practically all of the ore thus far produced has been shipped to Milwaukee and used in furnace mixtures.

The principal ore body, and the only one, up to this time, which has been developed, is known as Iron Hill and is situated about three miles northeast of the town of Waukon, the county seat of Allamakee county. Iron Hill is the highest point in the county and forms the divide between Village creek and the Oneota river. The summit of the ridge reaches some 200 feet above the water of the creek. The hill trends east and west, has an area of more than half a square mile and is crowned by the ore beds which extend farthest down the south slope. The lowest level ascertained, where the beds appear to be in place, is about fifty feet above Village creek. Detached bowlders and fragments of ore are encountered in prospect holes at much lower levels. The hill has been exploited thoroughly by sinking numerous test pits and the ore body is reported to attain a maximum thickness of 135 feet. The test pit records show that the underlying limestone forms an almost level floor, slightly dipping towards Village creek. The major portion of the ore body rests upon a Galena-Trenton base, though an inconsiderable portion appears to extend down to the Saint Peter sandstone, probably brought about through "creep" produced by the undercutting of the creek.

The ore is concretionary, the concretions varying in size from a fraction of an inch to aggregations several feet in diameter, and are imbedded in an ochreous clay matrix. While some of the concretions contain stained clay cores, many are hollow and the beds when viewed *en masse* present a strikingly cavernous appearance. The caverns vary in size from one to a few inches and possess the spheroidal shapes usual to nodular structures. Irregular caverns of larger size are not uncommon. Scattered throughout the ore body are occasional chert or flint nodules, sometimes occurring singly, at other times in aggregation masses of considerable extent. In the latter the individual cherts are cemented together by the hydrated oxide of iron, which often includes a liberal admixture of water worn quartz grains, varying from sand

Pit of the Waukon Iron Company, showing the nodular character of the ore.

to pebbles of half an inch in diameter. The conglomeratic bowlders are more frequent at certain levels than others but appear to have no definite limits. They are often closely associated with the richest ore bodies.

Fractures and joint planes are not prominent features and when they occur may be attributed usually to the present topography and are supposedly due to creep.

The principal ore present appears to be the hydrated sesquioxide or iron or limonite, somewhat siliceous, as is shown by the analysis herewith appended:*

	Sample No. 275 G E. Patrick, Analyst	Waukon Ore, (Black) Fischer of Milw'kee, Analyst	Waukon Ore, (Yellow) Fischer of Milw'kee, Analyst	Waukon Ore, J. B. Weems, Analyst	Average.
Metallic Iron	54.32	58.54	54.79	57.75	56.35
Silica and insoluble	......	4.00	5.12	3.26	4.13
Water	......	......	11.92	10.92	11.42
Phosphoric Acid	0.13	......	0.13	0.72	0.32
Lime	....	......	0.70	......	....
Magnesia	....	......	Tr.	......	......
Alumina	......	......	Tr.	0.25	......
Manganese Oxide	......	......	Tr.	0.20	......
Sulphur	None	......	......	......	......

Aside from the limonite the ore appears to be in part hematitic. This is shown by the analyses of certain selected samples which gave nearly 67 per cent iron. Pure limonite contains only 59.8 per cent iron while hematite may reach 70 per cent when pure. The phosphorus percentage shows considerable variability, doubtless owing in part to the method of sampling. The samples showing the largest amount were taken from single concretions and cannot be considered to fairly represent the general ore body. Analyses made for the purpose of grading the ore placed on the market show the phosphorus constituent well within the danger limit, rarely exceeding 0.09 for pure phosphorus. Similar variations may be noted in the sulphur content. The sulphur present is doubtless in the form of the pyrite and is not often detected.

Professor Calvin in his memoir on Allamakee county demonstrates conclusively that the ore beds cannot be accounted for

*Analyses in duplicate were made by Mr. F. M. Weakley, of the department of Mining Engineering, of an average sample of the ore, which gave: Phosphorus, 0.0108 per cent and Manganese 0.65 per cent.

through secular decay and concentration in place of the iron constituent contained by the rocks, but that some secondary process of concentration must be taken into account. A single argument put forward by him is sufficient to render impossible any *in situ* explanation. He states that a liberal estimate of the stratified rocks removed from the district would not exceed 1,000 feet, and granting the presence of one per cent of iron on the average, and no loss during the process of degradation, the maximum thickness of the ore residuum could not exceed ten feet, an amount less than one-tenth of the actual thickness reported. His conclusion is that the ore beds were accumulated through the well known processes of decaying organic matter and circulating water, generally known as the "bog iron ore" process. While the "bog iron ore theory" explains the greater portion of the deposit, the presence of the irregularly arranged siliceous concretions, and the water worn quartz pebbles, render obvious the complexity of the conditions which prevailed during the time of accumulation.

Some years since, the Waukon Iron Company was organized to exploit Iron Hill and if circumstances proved favorable to mine and ship ore. The chief organizers and owners live in the county. The first serious attempt to develop the property was during the season of 1899. Early in 1901 a complete modern ore washing plant was installed and put into operation.

The beds are easily worked. As there is almost no stripping the open pit method is adopted. The usual practice is to break up the ore by the use of heavy charges of black powder. The larger bowlder concretions are further reduced by breaking with dynamite. The ore is loaded by hand into two-ton, home made wooden ore cars and hauled by horses to the washer. A double track leads from the pit to the washer, the grade favoring the loaded car.

The plant is conveniently located at the head of a ravine which leads down to Village creek, and is equipped with a McClanahan-Stone outfit complete, manufactured by the McClanahan-Stone Machine Company of Hollidaysburg, Penn. The ore from the car is dumped into a hopper which leads to a single roll crusher. The crushed ore passes directly into a single twenty-five foot log

Waukon Iron Mine, close view, showing the cavernous character of the ore. *a* represents one of cherty, concretionary masses.

washer, consisting of steel shaft armed with steel blades rigidly bolted to the shaft. Here water is admitted at the rate of 300 gallons per minute when the plant is operated at its full capacity. The ore from the log enters a standard McClanahan-Stone double shell screen. Arrangements are made so that an additional fifty gallons of water per minute may be introduced here if desired. The screenings fall directly into an inclined trough, leading to a sluice box which carries the waste down the gully. The washed ore is caught by a steel pan conveyor which carries the ore to the storage bins. The chert nodules and other impurities are removed by hand as the ore passes over this belt. An overflow bin has been provided some distance from the plant and is connected by an elevated cable conveyor. The capacity of the plant is 300 tons per ten hour shift. Power is supplied by a Fairbanks-Morse 100-horse power boiler and a Frost slide valve engine of eighty-five indicated horse power. Water is obtained from a well 500 feet in depth on the

Fig 1. General view of ore washing plant, Waukon Iron Company. The foundations were built with a view of putting in a second washer and thus doubling the capacity of the plant.

premises. A constant supply is maintained by the use of an open storage reservoir of 12,000 barrels capacity. The machinery thus far installed is thoroughly modern, well housed, and well kept.

Iron Hill cannot take rank as an iron producer until better transportation facilities are provided. The Waukon branch of the Chicago, Milwaukee & Saint Paul Railway ends some three miles distant as the crow flies, but according to recent surveys would require an actual extension of some five miles to bring the plant into connection. A water grade can be secured down Village creek to the Mississippi river, but in this case a new line of railway from fifteen to eighteen miles in length would be required. At the present time it is difficult to say which would be the more practicable route. The concensus of opinion slightly favors Village creek as it is the most direct to navigable water. The industry can scarcely be said to be more than initiated. The output for the past year represents the plant running at its full capacity for less than twenty days. This state of affairs was due almost wholly to bad shipping facilities, the cost of transferring the ore from the washer to the car being fifty cents per ton, an amount greater than is paid for transporting Lake Superior ore from Duluth to Cleveland and other lake ports.

The ore would yield readily to the steam shovel, which would be more independent of weather and labor difficulties. Some form of rope haulage would effect a saving worthy of consideration. At present two horses and two drivers are required.

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thirty and forty feet high and miniature gorges and canyons are common. These conditions account for Wild Cat's cave in section 11, Pleasant Valley township. Often covered with mosses, ferns and lichens, the walls of these canyons are most picturesque.

Lizard creek flows through a valley of more maturity than any other of the tributaries of the Des Moines within the county. Of the two branches, the North Lizard is the major stream. Badger, Deer, Brushy and Skiller creeks are confined within sharp ravines in the drift, till they near the river, where for one or two miles they have cut through the indurated rock to a depth of ten or fifteen feet.

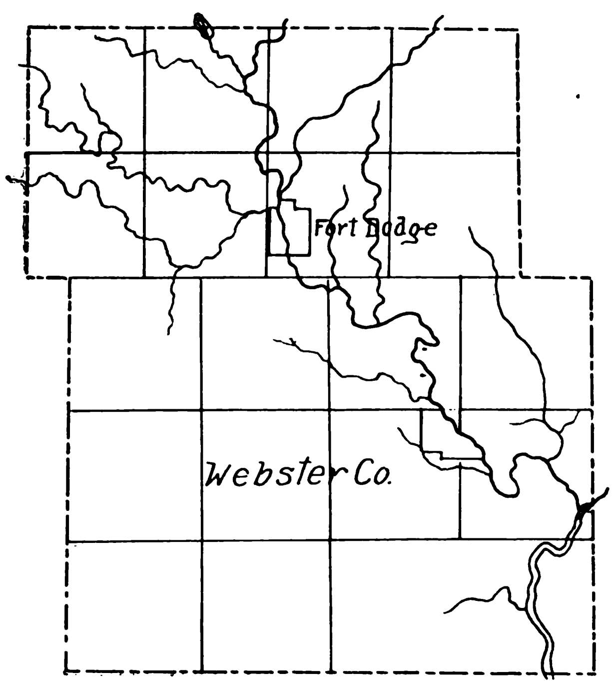

FIG. 2. Sketch of Webster county which shows the immature state of drainage.

DRAINAGE.

The entire county is drained by the Des Moines river and its tributaries. Most of the branches rise within or barely outside of the county and while still within its limits unite with

the parent stream. Lizard, Soldier, Deer, Holaday, Brushy, Skiller and Prairie creeks answer this description. East and West Buttrick creeks, which drain four townships in the southwestern corner of the county, contribute their waters to the Raccoon

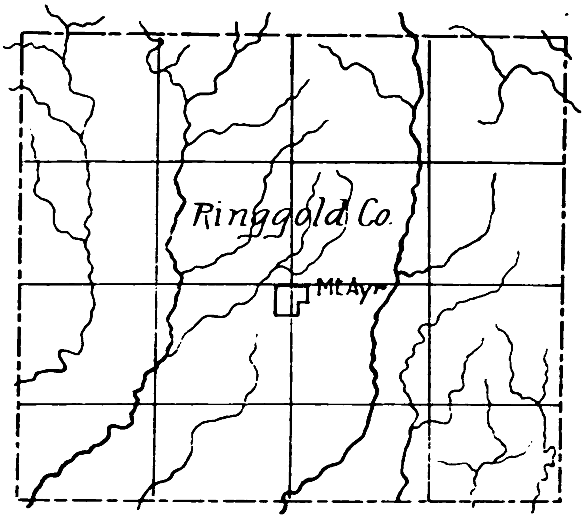

FIG. 3. Sketch of Ringgold county which brings out the maturity of its drainage.

which they meet in Greene county. The drainage system is not elaborate. None of the creeks in the county are perennial farther than a mile from their mouths. The creeks have no well developed subordinate feeders, and large stretches of country are dependent on artificial drainage. The contrast that Webster county presents in this particular with certain other parts of the state is made plain by a map drawn on a scale as limited as that of the Railroad Commissioners. The accompanying sketches which reproduce Ringgold and Webster counties illustrate fairly the difference in drainage between Webster county and the southern part of the state. Any county in the three tiers near the southern boundary would serve for contrast as well as Ringgold. Sloughs and ponds are common throughout Webster county, their number and size varying with the season of the year. The percentage of the land that is for this reason kept from cultivation, however, is not great. Yearly the number of ponds is being reduced by artificial drainage.

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through secular decay and concentration in place of the iron constituent contained by the rocks, but that some secondary process of concentration must be taken into account. A single argument put forward by him is sufficient to render impossible any *in situ* explanation. He states that a liberal estimate of the stratified rocks removed from the district would not exceed 1,000 feet, and granting the presence of one per cent of iron on the average, and no loss during the process of degradation, the maximum thickness of the ore residuum could not exceed ten feet, an amount less than one-tenth of the actual thickness reported. His conclusion is that the ore beds were accumulated through the well known processes of decaying organic matter and circulating water, generally known as the "bog iron ore" process. While the "bog iron ore theory" explains the greater portion of the deposit, the presence of the irregularly arranged siliceous concretions, and the water worn quartz pebbles, render obvious the complexity of the conditions which prevailed during the time of accumulation.

Some years since, the Waukon Iron Company was organized to exploit Iron Hill and if circumstances proved favorable to mine and ship ore. The chief organizers and owners live in the county. The first serious attempt to develop the property was during the season of 1899. Early in 1901 a complete modern ore washing plant was installed and put into operation.

The beds are easily worked. As there is almost no stripping the open pit method is adopted. The usual practice is to break up the ore by the use of heavy charges of black powder. The larger bowlder concretions are further reduced by breaking with dynamite. The ore is loaded by hand into two-ton, home made wooden ore cars and hauled by horses to the washer. A double track leads from the pit to the washer, the grade favoring the loaded car.

The plant is conveniently located at the head of a ravine which leads down to Village creek, and is equipped with a McClanahan-Stone outfit complete, manufactured by the McClanahan-Stone Machine Company of Hollidaysburg, Penn. The ore from the car is dumped into a hopper which leads to a single roll crusher. The crushed ore passes directly into a single twenty-five foot log

Waukon Iron Mine, close view, showing the cavernous character of the ore. *a* represents one of cherty, concretionary masses.

washer, consisting of steel shaft armed with steel blades rigidly bolted to the shaft. Here water is admitted at the rate of 300 gallons per minute when the plant is operated at its full capacity. The ore from the log enters a standard McClanahan-Stone double shell screen. Arrangements are made so that an additional fifty gallons of water per minute may be introduced here if desired. The screenings fall directly into an inclined trough, leading to a sluice box which carries the waste down the gully. The washed ore is caught by a steel pan conveyor which carries the ore to the storage bins. The chert nodules and other impurities are removed by hand as the ore passes over this belt. An overflow bin has been provided some distance from the plant and is connected by an elevated cable conveyor. The capacity of the plant is 300 tons per ten hour shift. Power is supplied by a Fairbanks-Morse 100-horse power boiler and a Frost slide valve engine of eighty-five indicated horse power. Water is obtained from a well 500 feet in depth on the

Fig 1. General view of ore washing plant, Waukon Iron Company The foundations were built with a view of putting in a second washer and thus doubling the capacity of the plant.

premises. A constant supply is maintained by the use of an open storage reservoir of 12,000 barrels capacity. The machinery thus far installed is thoroughly modern, well housed, and well kept.

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INTRODUCTION.

LOCATION AND AREA.

Webster county is somewhat north and west of the center of the state. Four counties lie between it and the Missouri river while three separate it from the Minnesota boundary. The county includes twenty townships of thirty-six square miles each, two of which are subdivided for the purposes of local government, so that twenty-two townships are named on the map. The second correction line passes between townships 98 and 99 north, and throws the northern part of the county two miles to the west, breaking its otherwise regular outline. Humboldt county bounds it on the north, Wright and Hamilton on the east, Boone and Greene on the south and Calhoun and Pocahontas on the west. Its location on the Des Moines river was more significant in earlier days when greater dependence was placed upon water for power and transportation, yet the beauty of the finely wooded valley is a constant source of satisfaction to the inhabitants of the region. It lies in the center of a great agricultural region of which every county in Iowa forms a part.

PREVIOUS GEOLOGICAL WORK.

Some of the earliest geological work undertaken in the state was carried on in Webster county. The Des Moines river exposes along its banks the indurated beds, and gives at times sections of rock and drift 200 feet in thickness. These greatly facilitate geological study. The unique deposit of gypsum is attractive to the student on account of the theoretical problems that it presents, and to others it is interesting on account of its practical value.

In the year 1849 Owen* made a hurried trip up the Des Moines river, noticed the gypsum in Webster county and made certain deductions in regard to its age. In [illegible] Worthen† visited the

* Geology of Wis., Iowa and Minn., [illegible] Philadelphia, [illegible]

† Geology of Iowa, Vol. I, [illegible]

region and came to the conclusion that the gypsum does not lie conformably on the Coal Measures. Hall* in 1858 and McGee† in 1884 considered the stratigraphic relationship and age of the gypsum. Webster county was included in the geological studies of C. A. White and references to its coal and gypsum are made in his annual reports of 1868 and 1870.‡ In these reports White pointed out the great value of the Webster county gypsum, and urged that it be developed so that the state might furnish the stucco and land plaster used within its borders. His judgment of the worth and extent of the gypsum has been verified, with but one exception. It has failed to meet his expectation as a building stone. White also called attention to deposits of celestine along the Des Moines river and at the mouth of Soldier creek, and gave a description of the mineral as it occurs at these points. In 1880 Upham studied the inner Wisconsin moraine known as the Gary, and called attention to a morainic tract between Fort Dodge and Tara, which he thought might be associated with this moraine.

Keyes§ reported quite fully on the gypsum area in 1893. He outlined the position and extent of the deposit, considered its stratigraphic relationships and stated clearly the conditions under which in all probability it was formed. He emphasized the economic value of the gypsum and described the methods of quarrying and milling at that time in use. In the preceding year the coal deposits of Webster county were considered¶ in connection with those of other parts of the state. The report included analyses of a number of samples of coal obtained in the vicinity of Fort Dodge.

Arthur C. Spencer, in a paper presented to the Iowa Academy of Sciences, described the crystals of gypsum common about Fort Dodge.**

* Geology of Iowa, Vol. I, p 147. 1858.
† Tenth U. S. Census, Vol. X, Building Stones, p. 258, Washington. 1884.
‡ First Ann. Rept. State Geologist. pp. 26-27, 1868; 2d Ann. Rept., pp 135-140, 1868. Geology of Iowa, Vol. II, pp. 293 and pp 254-256. Analyses of Fort Dodge coal are given on pages 375-376.
‖ Ann. Rept. State Geologist, Minnesota, p. 305, 1880
§ Iowa Geol. Surv., Ann. Rept., Vol. III, 1893, pp. 259-304.
¶ Iowa Geol. Surv., Vol. II, pp. 197-210. 1892.
** Proc. Iowa Acad. Sci, Vol. II, pp. 143-145. 1894.

PHYSIOGRAPHY.

TOPOGRAPHY.

Webster county lies wholly within the area that was covered by the last great ice invasion, and the drift of this ice sheet, called the Wisconsin, forms almost everywhere the surface material. Limited areas covered by glacial material that has been recently reworked by streams, or by detritus formed by the very recent weathering of cliffs along streams, are the only regions not drift covered. So recently was this drift deposited that erosion has but slightly contributed to the topographic features of the county. Only in the immediate vicinity of the Des Moines river and its tributaries are the results of water action apparent. Viewed from the valleys of the streams, the landscape seems extremely rugged, and it is a matter of constant surprise that, in a region so typically prairie, scenery so beautiful abounds. The sides of the valley are steep and well wooded from top to bottom. After ascending the sharp slope, however, the climber finds himself at once on the level prairie where often for miles he can see the stream as it flows through its V-shaped valley.

The following table of elevations indicates for the country a very uniform surface, with a slight slope toward the south:

TOWN.	AUTHORITY.	ELEVATION.
Clare	C., R. I. & P. R. R.	1,197
Tara	C., R. I. & P. R. R.	1,126
Moorland	C., R. I. & P. R. R.	1,146
Callender	C., R. I. & P. R. R.	1,151
Gowrie	C., R. I. & P. R. R.	1,138
Barnum	Ill. Cent. R. R.	1,178
Fort Dodge	Ill. Cent. R. R.	1,032
Judd	Ill. Cent. R. R.	1,114
Carbon	Ill. Cent. R. R.	1,118
Duncombe	Ill. Cent. R. R.	1,111
Dayton	C. & N. W. Ry.	1,084

All of the elevations cited give the upland level at the point named except at Fort Dodge and Dayton. The Illinois Central station at Fort Dodge is part way down the Des Moines river slope, while the Chicago & Northwestern station at Dayton is in the valley of Skiller creek. Barometric observations show that the upland level at these points is about 1,140 feet, which corresponds with the level of the rest of the county. The elevation at

Clare, the highest town in the county, is due to morainic conditions.

The southern half of the county presents a typical Wisconsin drift plain and includes areas that are remarkably level. From an elevation of only a few feet the country may be seen for miles in all directions. Clay and southern Elkhorn townships form such a great level tract. One exception to the otherwise level surface of this portion of the county must be noted. Three miles east of Gowrie, in the northeast corner of section 9, Lost Grove township, is Coon Mound. Its height is fifty feet and the dimensions of its base are about 500 by 300 feet, the longer axis extending north and south. It rises abruptly from the prairie and stands alone, save for a few low ridges to the west. The little school house on its summit is a conspicuous object for miles around.

The surface features of the northwestern part of the county differ somewhat from those of the southern half. Hills and ridges are common which cannot be associated with erosive agencies that generally give rise to such topographic features. These hills and ridges may roughly be grouped in two series, both extending east and west, about three miles apart. One follows the northern county line and includes the northern sections of Jackson and Deer Creek townships, and crosses the river into Badger township. Its average width is two miles. Within this broken region are level stretches of considerable extent. In years past one of these was flooded and bore the name of Bass lake, the depth of which is said to have been four feet. In 1890 Bass lake was drained into Bass creek by a ditch four feet deep. At present the area that it once covered is wholly under cultivation. The other series of hills and ridges extends across northern Douglas township, north of Lizard creek, with occasional outliers farther south across the creek. This series appears again across the river in section 19, Badger township. The Ainsworth home and farm buildings, in section 11, Douglas township, are on the crest of one of the ridges in this belt.

The valley of the Des Moines river is the most interesting topographic feature that the county presents. Throughout its course within the county the river has cut through the drift and

indurated rocks to a depth varying from 150 to 200 feet. West of Badger, from the prairie at the top of the river bluffs to water level, the descent is 140 feet. At Fort Dodge the upland level is reached at the Mason City and Fort Dodge railway station. The river lies three-fourths of a mile to the west and 180 feet below this point. Across the river the bluffs rise again sharply to the prairie level, the ascent of nearly 200 feet being made within 250 yards. At Blandon's mill, three miles below Fort Dodge, the valley is 165 feet deep, at Coalville 175 feet, and at Lehigh, the water is 190 feet below the upland plain.

High up in the valley, 125 feet above the water, a prominent gravel terrace frequently appears. Round Prairie at Fort Dodge, on which the fair grounds were located, is a part of this terrace, which is here unusually wide. It is well developed south of West Fort Dodge. In width it varies from twenty to [illegible] yards. Below this, sixty feet above the water, fragments of an alluvial terrace are frequently found, commonly called the second bench. The alluvial bottom lands are seldom more than [illegible] yards wide. The broadest point in the Des Moines river valley is at the mouth of the Boone river, where the width of a mile is attained. Standing in the center of the alluvial plain at this point is a large symmetrical hill of circumdenudation fifty feet high and [illegible] feet broad.

At many points the river is vigorously attacking the base of the bluffs. Landslides result in which at times considerable quantities of material are involved. Where landslides have recently occurred the upper bluffs are so steep that they can scarcely be climbed.

In their upper courses the tributaries of the Des Moines in Webster county have not cut through the drift and commonly have very indifferent valleys. Generally rising in a slough they follow for some miles the natural inequalities of the surface adapting themselves to existing conditions rather than [illegible] materially altering them. Near the river the creeks have cut into the indurated rocks and the lower portions of their valleys appear more mature. A soft Carboniferous sandstone underlies the drift in the southern part of the county and through this Brushy creek has cut to a depth of sixty feet. [illegible] escarpments

thirty and forty feet high and miniature gorges and canyons are common. These conditions account for Wild Cat's cave in section 11, Pleasant Valley township. Often covered with mosses, ferns and lichens, the walls of these canyons are most picturesque.

Lizard creek flows through a valley of more maturity than any other of the tributaries of the Des Moines within the county. Of the two branches, the North Lizard is the major stream. Badger, Deer, Brushy and Skiller creeks are confined within sharp ravines in the drift, till they near the river, where for one or two miles they have cut through the indurated rock to a depth of ten or fifteen feet.

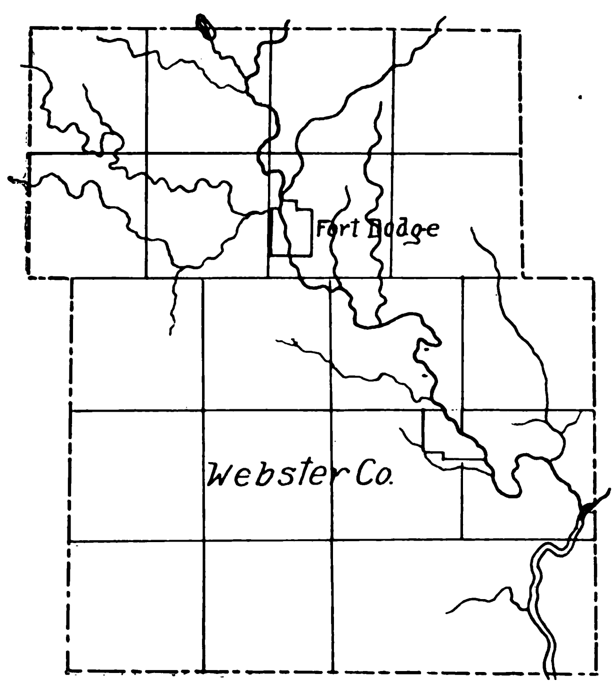

FIG. 2. Sketch of Webster county which shows the immature state of drainage.

DRAINAGE.

The entire county is drained by the Des Moines river and its tributaries. Most of the branches rise within or barely outside of the county and while still within its limits unite with

the parent stream. Lizard, Soldier, Deer, Holaday, Brushy, Skiller and Prairie creeks answer this description. East and West Buttrick creeks, which drain four townships in the southwestern corner of the county, contribute their waters to the Raccoon

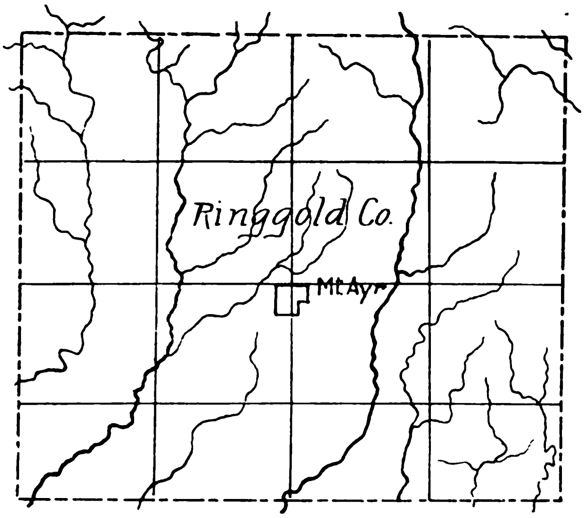

FIG. 3. Sketch of Ringgold county which brings out the maturity of its drainage.

which they meet in Greene county. The drainage system is not elaborate. None of the creeks in the county are perennial farther than a mile from their mouths. The creeks have no well developed subordinate feeders, and large stretches of country are dependent on artificial drainage. The contrast that Webster county presents in this particular with certain other parts of the state is made plain by a map drawn on a scale as limited as that of the Railroad Commissioners. The accompanying sketches which reproduce Ringgold and Webster counties illustrate fairly the difference in drainage between Webster county and the southern part of the state. Any county in the three tiers near the southern boundary would serve for contrast as well as Ringgold. Sloughs and ponds are common throughout Webster county, their number and size varying with the season of the year. The percentage of the land that is for this reason kept from cultivation, however, is not great. Yearly the number of ponds is being reduced by artificial drainage.

The Des Moines river crosses the county, entering near the center of the northern boundary and leaving at the southwestern corner. Its course is sinuous, measuring sixty-five miles in the county, while thirty-five miles is the straight line distance from its entrance to its exit. In width the Des Moines in Webster county varies from 100 to 200 yards, and in average depth from perhaps two feet in summer to seven feet during the rainy periods in the spring months. In addition to the main creeks which will be mentioned separately, there are along the Des Moines many ravines which in time of rain are tributary to it. These ravines extend from the river only a short distance, and often there are long stretches where the bluffs overlooking the river are unbroken.

Lizard creek is the largest stream tributary to the Des Moines

FIG. 4. The Des Moines valley at the mouth of the Boone river. The Boone appears in the foreground, while the Des Moines is hidden by trees.

in Webster county. It drains the five northwestern townships. Two branches of slightly differing size unite two miles from its mouth to form the main stream. The general course of both

branches is southeast, save for a few miles near their junction where the southern branch turns north to meet its companion.

Deer creek rises barely across the line in Humboldt county and after traversing Deer Creek township in Webster county empties into the Des Moines. It has no tributaries, aside from short ravines supplying water in time of rain, and drains the region for only a short distance on either side of its immediate valley.

Prairie creek rises in Elkhorn township which it crosses diagonally. Entering Otho township it flows for some distance within two miles of the Des Moines river in a course nearly parallel before it unites with that stream. All of the creeks so far described are on the west side of the river.

Brushy creek, like most of the tributaries on the east side of the Des Moines in Webster county, flows almost due south. It rises at the northern edge of the county and for two-thirds of the length of the county flows within three miles of its eastern boundary.

Holaday creek which is three miles west of Bushy creek rises in the extreme northeastern corner of Badger township and flowing almost directly south drains western Cooper and Pleasant Valley townships. Throughout its course it is nearly parallel to Brushy creek.

Soldier creek rises in the northeastern corner of the county and differs from other streams on the east side of the river in this vicinity by flowing southwest, meeting the Des Moines at Fort Dodge. Like all of the secondary streams within the county it discharges a great quantity of water during the rainy season and is insignificant during the summer months.

East and West Buttrick creeks, tributaries of the Raccoon, which drain the southwestern part of the county, like all the minor water courses within the county, appear extremely immature. Reasons for the extreme youth of the drainage system will be considered later in connection with the Pleistocene deposits. Boone river unites with the Des Moines in southeastern Webster county.

STRATIGRAPHY.

General Relations of Strata.

Excepting limited Carboniferous outliers, Webster county contains the most northern of the Iowa Coal Measures. These lie just beneath the drift throughout all of the southern and the greater part of the rest of the county. The Saint Louis limestone, a characteristic member of the Lower Carboniferous, underlies the drift at certain points in the northern part of the area, and appears along the Des Moines in two places well to the south where the stream has cut through the Coal Measures which are there thin. Within the Coal Measures, in the central part of the county, probably during some part of the Permian or Jura-Trias period, a hollow of considerable extent was filled with saline deposits, the gypsum beds.

After being exposed as surface rock for a long period, the coal and associated shales, gypsum and limestone, were covered by material deposited by three great glaciers. Between the invasion of these ice sheets there was a considerable interval of time. Of the material deposited by the first and second glaciers the greater part was subsequently removed by erosion, stream and glacial, all that now remains appearing in scattered beds of badly rusted and decayed gravel. A later ice sheet deposited great quantities of clay, pebbles and bowlders, which still remain and slightly modified by plant and animal life form the soil of the region.

The relation of the formations is shown in the following table:

GROUP.	SYSTEM.	SERIES.	STAGE.	FORMATION.
Cenozoic.	Pleistocene.	Recent.		Tufa, Humus, Alluvium.
		Glacial.	Wisconsin.	Drift.
			Aftonian(?)	Gravel.
Paleozoic.	Carboniferous.	Permian(?)		Gypsum Red Shale and Sandstone.
		Upper Carboniferous or Pennsylvanian.	Des Moines.	Coal. Sandstone. Shale.
		Lower Carboniferous or Mississippian.	Saint Louis.	Limestone.

The Des Moines river gives a series of exposures nearly continuous across the county from north to south. Prairie creek reveals the indurated rocks for three miles west of the river in the center of the county. Near Fort Dodge sections occur near Soldier and Lizard creeks. Exposures along Holaday creek add greatly to our knowledge of the formations in the west central portion of the county. Near its mouth Skiller creek has cut through the drift and into the Coal Measures. Two Mile creek, near Fort Dodge, has excavated the ravine known as Gypsum Hollow, in which are revealed full sections of the gypsum beds with a few feet of the underlying shale and clay which are associated with them.

In addition to these natural exposures well data throughout the county and the records of holes sunk while prospecting for gypsum and coal are instructive.

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The Des Moines river gives a series of exposures nearly continuous across the county from north to south. Prairie creek reveals the indurated rocks for three miles west of the river in the center of the county. Near Fort Dodge sections occur near Soldier and Lizard creeks. Exposures along Holaday creek add greatly to our knowledge of the formations in the west central portion of the county. Near its mouth Skiller creek has cut through the drift and into the Coal Measures. Two Mile creek, near Fort Dodge, has excavated the ravine known as Gypsum Hollow, in which are revealed full sections of the gypsum beds with a few feet of the underlying shale and clay which are associated with them.

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Carboniferous System.

MISSISSIPPIAN SERIES.

Only the upper member of this series, the Saint Louis limestone, is exposed in Webster county. It frequently appears along the Des Moines river from the northern boundary of the county south to Lehigh and for two miles back from the river, to the east on Soldier creek, and for an equal distance to the west on Lizard creek.

In all of these exposures the limestone is quite consistent both in its lithological and stratigraphic characteristics. It is made up of layers of quite pure limestone, varying in thickness from an inch to a foot. Above the limestone layers from three to six feet of calcareous sandstone are common. Above the sandstone from six to ten feet of shaly marl are often found. A definite layer of this marl is extremely rich in fossils, while the rest is barren. Frequently the limestone layers are brecciated. The layers are folded gently, resulting in undulations in the stone averaging about thirty feet in length with a vertical distance of four feet from crest to hollow. Vertical cracks are common, but no faulting was observed and the stone shows only slightly the defects of crushing.

A typical section is found on the right bank of the Lizard, a mile from Fort Dodge, in Douglas township, section 24, center.

LIZARD CREEK SECTION—SAINT LOUIS LIMESTONE

		FEET.
4.	Fossil-bearing marl, *Spirifer littoni* Swallow, *Pugnax ottumwa* White, *Seminula subquadrata* Hall, *Dentalium* sp., abundant	6
3.	Marl, gray, without fossils, containing many small selenite crystals	40
2.	Sandstone, yellow, moderately hard, showing little lamination, calcareous	2
1.	Limestone, slightly folded, in definite layers, average thickness of largest eight inches, in places brecciated, though not showing a layer that is brecciated throughout, as in exposures in the Des Moines river north of Fort Dodge.......	17

Above the marl is a drift slope seventy feet high, while Coal Measure shales, which probably lie between the marl and the drift, are concealed by the wash of the slope and the growth of vegetation.

The fossil-bearing layer of marl was cut through by the Illinois Central railroad and a great number of excellent specimens may be picked up along the cutting. Fossils are also abundant on the slope of Lizard creek. The sandstone, which generally lies just above the limestone, though seldom absent, varies greatly in thickness in different localities. At the wagon bridge near the mouth of Lizard creek a sandstone layer is present also in the limestone.

SECTION AT MILLER'S QUARRY, NEAR THE STONE BRIDGE OVER SOLDIER CREEK IN FORT DODGE.

		FEET.
7.	Soil	2
6.	Gravel, fresh, cross-bedded	10
5.	Clay, yellow, not jointed, unleached, many limestone pebbles	15
4.	Soil and clay mingled, both unleached, soil dark and containing many wood fragments	15
3.	Sand, uncemented, containing lumps of coal and large pieces of wood, in layers varying greatly in color from white to gray	8
2.	Calcareous sandstone, a single layer very firm	1½
1.	Limestone, layers coarse, often two feet thick, stone of even fine texture, no fossils	25

In the creek bed at the foot of this exposure the limestone gives place again to calcareous sandstone, the thickness of which could not be determined.

A little above Miller's quarry, on Soldier creek, the Saint Louis limestone gives place to Coal Measure shales. One-half mile further up Soldier creek in Cooper township, section 19, Nw. ¼, the limestone again comes to the surface and appears for 200 feet in the creek bed.

Following the river north from Fort Dodge, limestone appears continuously for two miles. On the west bank it underlies the

alluvium in the river flat. On the east side it appears beneath bluffs or Coal Measure shales and sandstone, which rise fifty feet above it. The limestone is exposed from the water's edge upward from twenty to forty feet, often forming a continuous mural escarpment for a considerable distance.

The section given below, taken in Cooper township, section 7, Sw. 1/4, is typical for this series of exposures:

		FEET.	INCHES.
13.	Sand	5	
12.	Limestone layer	1	
11.	Limestone layer with persistent band of flint one inch thick	1	2
10.	Limestone layer	2	6
9.	Limestone layer	1	
8.	Limestone layer	1	
7.	Limestone, at some points massive and others showing layers slightly distinguishable	4	
6.	Limestone layer, light color		1
5.	Limestone layer	1	
4.	Limestone layer	1	
3.	Sandstone, in places containing a flint band one inch thick		6
2.	Limestone layer	1	6
1.	Sandstone to water's edge	1	6

The next section given is around the bend of the river, a mile above where the section just recorded was taken and just above the old coal mines two miles north of Fort Dodge, in Cooper township, section 7, Sw. 1/4:

		FEET.
3.	Drift	4
2.	Coal Measure shales, fissile, very ferruginous	10
1.	Limestone, with characteristics of the Saint Louis, on which the Coal Measures rest unconformably	10

Farther up the stream the surface of the limestone dips down at an angle of ten degree and soon disappears below water level. Within half a mile it emerges again and underlies the lower alluvial terrace to a point about a mile above the mouth of Badger creek, where it gives place to sandstone. This portion of the

river valley is unusually broad and is doubtless underlain with Saint Louis limestone. The alluvium over the limestone is very thin and the sandstone, which at many points appears in and over the Saint Louis, is here absent.

After passing numerous sandstone exposures, which will be considered under Carboniferous deposits, the limestone is again encountered one-half mile above Badger bridge, on the east bank of the river. At this point appear:

		FEET
3.	Brecciated limestone	4
2.	Covered so that the nature of the rock is concealed	3
1.	Calcareous sandstone appearing at water level.	

On the west bank a cliff shows:

		FEET.
3.	Sandstone, red, soft, thin-bedded, without joints, with coating of calcium carbonate over the rock in all of the cracks	20
2.	Covered by talus	15
1.	Limestone partly concealed by talus, brecciated, with much quartz and many layers of flint	20

Similar exposures continue to the north. Within eighty rods of the county line there appear:

		FEET.
2.	Limestone, brecciated in layers 8 to 12 inches	3
1.	Limestone, fine-grained, almost lithographic, in layers averaging 8 inches	6

The stone here is arched and folded more than at any other place visited in the county.

The most northern limestone exposure of any size in the county is forty rods south of the county line. At this point we have:

		FEET.
8.	Drift	2
7.	Gravel	1
6.	Marl	1
5.	Limestone, no fossils, layers one foot, six inches thick	12
4.	Sandstone, calcareous, yellow, fine-grained	6

alluvium in the river flat. On the east side it appears beneath bluffs or Coal Measure shales and sandstone, which rise fifty feet above it. The limestone is exposed from the water's edge upward from twenty to forty feet, often forming a continuous mural escarpment for a considerable distance.

The section given below, taken in Cooper township, section 7, Sw. ¼, is typical for this series of exposures:

		FEET.	INCHES.
13.	Sand	5	
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11.	Limestone layer with persistent band of flint one inch thick	1	2
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1.	Limestone, with characteristics of the Saint Louis, on which the Coal Measures rest unconformably	10

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6.	Marl	1
5.	Limestone, no fossils, layers one foot, six inches thick	12
4.	Sandstone, calcareous, yellow, fine-grained	6

	FEET.
3. Limestone, layers six to twelve inches......	4
2. Limestone, brecciated, containing much quartz and flint, very irregularly bedded	6
1. Limestone, evenly bedded to water's edge..	3

The striking peculiarity of the limestone in the northern part of the county is the great amount of drusy quartz and flint that it carries, most of it in the upper brecciated layers. Frequently the masses weigh 200 pounds. Calcite is also abundant.

Going down the river from Fort Dodge nothing but Coal Measure deposits are seen until a point is reached one-fourth of a mile below the Minneapolis & St. Louis railroad bridge near Duncomb's mill, in Pleasant Valley township, section 5, Sw. 1/4. Here the Saint Louis limestone rises to the surface and appears ten feet above summer water level. The upper part consists of the characteristic marl with many specimens of *Pugnax ottumwa* and *Spirifer littoni.* The exposure is not a large one, and perhaps ten acres will include all of the limestone at the surface in the river bed. The next exposure of Saint Louis limestone down the river is half a mile below here, in section 8, Ne. 1/4. The limestone shows for a thousand feet along the stream and rises ten feet above the water level. The upper five feet are marly, and the lower five feet are made up of solid stone, heavily bedded. Some quarrying has been done at this point. The limestone may underlie the alluvium in the valley, which is here 1,000 feet wide. The alluvium above the marl is at least fifteen feet thick. Below Kalo in section 16, the limestone occupies two small areas in the river bed.

West of Fort Dodge the limestone is exposed in the bed of Lizard creek for one and a half miles, to the junction of the two branches. It shows also in the creek bed of each branch for half a mile. The geological map makes clear the location of the various exposures just described.

Relations of Saint Louis Limestone to Coal Measures and Gypsum.—Wherever contacts have been observed between the Saint Louis limestone and the Coal Measures there is a marked unconformity. The surface of the limestone is very uneven and was evidently exposed to erosion for a very long interval before the Coal Measures were deposited. A mile north of Fort Dodge the

Saint Louis limestone rises fifty feet above the river. A mile above this point the section already quoted shows that it descends to within two feet of the water, its place being taken by Coal Measure shales. To the south the limestone also descends, so that along the river at Fort Dodge only Coal Measure shales and sandstones are exposed. This is not due to an anticlinal fold, but to unequal erosion of the limestone.

Along Soldier creek, as will be shown by sections cited farther on, the gypsum at certain points rests directly upon the Saint Louis limestone. Not far from these exposures of gypsum and limestone the gypsum is replaced by Coal Measure shales. The marked unconformity between the gypsum and Coal Measures furnishes a partial explanation for these conditions. The unconformity between the limestone and Coal Measures is doubtless another factor that gives rise to this peculiar relationship of strata. The unevenness in the surface of the limestone before the Coal Measures were deposited would, after the shales were laid down upon it, bring the limestone nearer the surface at some points than at others. If the subsequent erosion of the Coal Measures were even the limestone would outcrop at certain points, while at others it would still be covered. Th Coal Measures were, of course, unequally eroded thus doubling the opportunities for exposures of limestone. It is not strange therefore that the gypsum, which later was deposited in Coal Measure depressions, should often lie directly on the Saint Louis, while near by the Coal Measures intervene.

PENNSYLVANIAN SERIES.

DES MOINES STAGE.

The productive Coal Measures of Iowa belong to the Des Moines stage of the Pennsylvanian series. These strata directly underlie the drift in most of the central and southern part of Webster county, the main exception being a strip extending across the center of the county from northeast to southwest, where gypsum intervenes. The Coal Measures consist of shale, coal, sandstone, fire clay and thin beds of argillaceous limestone and limonite. Productive coal seams are found at a number of points.

Fire clay is almost invariably found beneath the coal. The shales are fissile, generally arenaceous and free from line. They vary in color from very dark gray to yellow. At many points they abound in crystals of selenite. Prints of ferns, lepidodendrons, and calamite are often well preserved in them. Fossils taken from the pit of the Fort Dodge clay works have been identified by Professor Macbride as *Alethopteris lonchitica* Schloth., *Eremopteris flexuosa* Lesq., *Neuropteris* sp. (probably *hirsuta.*) Good specimens of *Ulodendron ellipticum* Sternb. were also found at the same place and with these specimens of *Sigillaria* and *Calamites* occur. Bands of clay ironstone varying in thickness from one to ten inches and nodules of the same material are not uncommon in the shale. In the center of the nodules there is often pyrites of iron. A peculiarity of the Coal Measure shales

FIG. 5. Portion of Lepidodendron found in the pit of the Fort Dodge Clay Works.

throughout the county is shown in the accompanying illustration. One bed of shale rapidly gives place to another or to sandstone in a way which suggests an unconformity, yet which lacks

at least one phase of the process to which that term is properly applied. It is hardly equivalent to the cross bedding so common in the Coal Measure sandstone, nor is it due to the thinning out of one bed. The material is of equal fineness across the section, and the laminæ are of equal thickness. The following explanation is suggested. The lower beds when formed con-

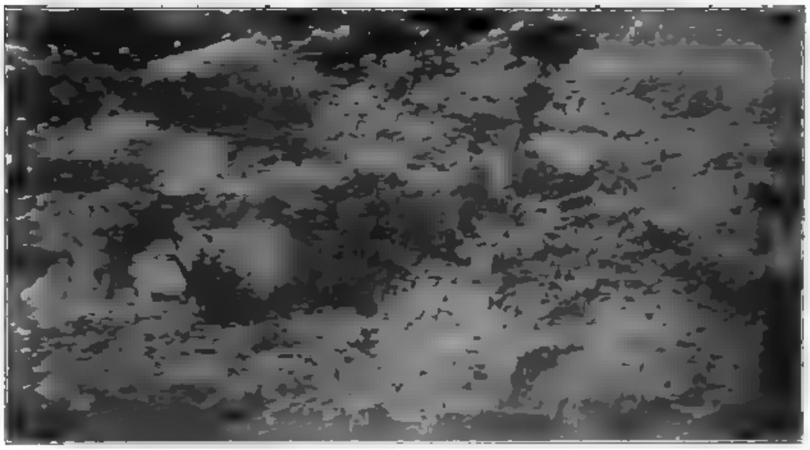


FIG. 6. View showing parallel deposition at the right, while toward the left there is a line along which, owing to current action, the parallelism is interrupted. Clay pit of Fort Dodge Brick and Tile works.

tinued parallel across the section. Current action, however, shortly after their deposition and while the material was yet plastic, being increased over the surface of the section shown in the picture on the right, scoured out some of the silt, producing the slope now shown in the lower bed. Subsequent changes in the current permitted deposition again, and the upper beds were laid down.

The Coal Measure sandstones are the striking stratigraphic feature in the southern part of the county where a maximum thickness of sixty feet is exposed. Most of the layers are ferruginous, but near Lehigh the upper courses at certain points are cemented with carbonate of lime. The bond between the grains is slight when iron is the cementing substance. The layers containing carbonate of lime, however, are firm and suitable for building. Typical exposures of these sandstones may be seen on Prairie creek in Otho township, section 35, the so-

called copperas beds, and at Wild Cat cave in Pleasant Valley township, section 11, Sw. ¼.

SECTION AT "COPPERAS BEDS" NEAR THE MOUTH OF PRAIRIE CREEK

		FEET.
4.	Drift	5-50
3.	Sandstone, cross-bedded, soft, ferruginous, containing concretions	30
2.	Sandstone, conglomeratic, containing large blocks of the sandstone found in the vicinity, with fossil wood in large pieces. The surface of this portion of the bluff is usually white with $Fe\,SO_4$	15
1.	Conglomerate, consisting of northern pebbles, quartz especially abundant, though some granites and greenstones, water-worn, small, none above half an inch in diameter, cemented by iron so that perhaps 25 or 30 per cent of the whole mass is iron. In the center there is a two-inch streak of clay ironstone and three inches of soft shale	4

The concretions in the sandstone are very abundant and of all sizes from a foot to a fraction of an inch. Many of the smaller ones are hollow. Cross-bedding is everywhere conspic-

FIG. 7. Concretionary structure in Carboniferous sandstone, near mouth of Prairie creek, Webster county.

uons. At times the laminæ are curiously contorted, not merely slanting, as is common in cross-bedding, but bent over so that they arch like a bow. Such a structure is difficult to explain. Lateral or vertical pressure on plastic, cross-bedded sand may account for it. Very common in the Coal Measure sandstones are small shining particles of selenite.

FIG. 8. Sandstone near the mouth of Prairie creek. 1. Conglomerate consisting of small foreign pebbles cemented by iron. 2. Coarse conglomerate containing large fragments of native sandstone.

The iron conglomerate, containing iron and northern pebbles, was found only near the mouth of Prairie creek and in a ravine a mile farther south. Perhaps one-half of the rock consists of

small pebbles and the rest of the cementing iron. The rock so formed is very hard and seems to weather very little. Where it has been long exposed to the air the pebbles have fallen out and the rock has a vesicular appearance, in color and structure resembling lava.

The coal seams of the county cannot be correlated to make a continued series. In the localities where coal has been found it seems to be limited to rather definite areas each only a few square miles in extent. Two, three and four seams may occur separated generally by only a few feet of shale. The districts now producing most of the coal are the Lehigh, Crooked creek and the Kalo and Coalville. Smaller quantities are mined at Tara, Limburg and at the old mines north of Fort Dodge.

The Lehigh coal belt is not more than two-thirds of a mile wide and extends from northeast to southwest across section 7, Webster township and section 13, Burnside township. It is crossed nearly in the center by the Des Moines river. On the west side of the river Crooked creek cuts through it, and coal is mined on this creek two miles from its mouth. On the east side of the creek the prospect holes of the Crooked Creek Railroad and Mining Company have found coal a mile back from the river. All of the mining has been done along the river and Crooked creek. The coal lies in four seams, one above the other, so that prospect holes often pass through more than one seam. The seams vary considerably at different points. All of the seams have produced or are producing coal, but the coal from the Tyson seam is regarded as the best and this seam up to date has been most extensively worked. The Harper seam is thirty feet above the water of the river; the Tyson is twenty feet above water level; the Pretty seam is ten to twenty feet below water level, while the Big is forty feet below the Pretty seam. The two seams above water level have been worked by drifting into the banks of the river, the banks of Crooked creek, and the sides of the numerous ravines in the vicinity. The Pretty seam and the Big seam are reached by shafts. The Big seam is said to lie at a uniform level, but the other seams are not so regular. The Tyson seam is never more than fifteen hundred feet wide, and it dips uni-

formly towards the center. There are no signs of faulting in the region.

The following is a composite section through the Lehigh coal seams:

		FEET.
9.	Drift	120
8.	Shale	20
7.	Coal, slate, six inches, Harper vein	0-2½
6.	Sandstone and shale	15
5.	Coal, Tyson seam	4
4.	Sandstone and shale	30
3.	Coal, Pretty seam	2-3
2.	Shale	30
1.	Coal, Big seam, four inches bone in center	3½-4½

The following is a record of a typical prospect hole in the Lehigh region. This hole was put down by the Crooked Creek Company at what is now their shaft No. 5, in the valley of Crooked creek*.

		FEET.	INCHES.
22.	Soil	10	
21.	Red shale	5	
20.	Light shale	6	
19.	Coal (Harper vein?)		6
18.	Light shale	4	6
17.	Sandstone	2	
16.	Shale	1	
15.	Black shale	3	
14.	Coal (Tyson vein)	1	
13.	Fire clay	9	
12.	Sandstone	1	
11.	Black shale	2	
10.	Sandstone	3	
9.	Black shale	4	5
8.	Coal		6
7.	Light shale	6	
6.	Dark shale	35	
5.	Coal (Pretty vein)	2	
4.	Dark shale	22	
3.	Light shale	2	
2.	Black shale	5	2
1.	Coal (Big vein)	3	

The Coalville coal basin includes five square miles in Pleasant Valley and Otho townships, parts of six sections. The coal

* Authority, Craig Coal Company

lies in three horizons, the lowest or cannel coal, second, a relatively thin and insignificant bituminous seam, and third, the upper bituminous, which is the most important. The upper

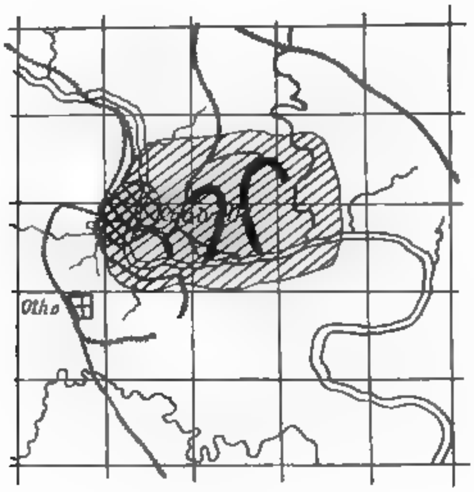


FIG. 9 The Coalville coal basin.

bituminous horizon is commonly regarded as made up of two seams, but this opinion is probably erroneous. The upper bituminous coal extends from Holaday creek on the east to a point not far beyond the river on the west. On account of the bend in its course, the river is again made the southern boundary, while its northern limit is approximately marked by the northern boundaries of sections 8, 9 and 10, Pleasant Valley township. A limited portion of this area, shown in figure 8, contains coal varying in thickness from six to eight feet. This is known as the "Big coal." The Big coal is confined to a curiously narrow and contorted strip. It is rarely over 300 feet wide and often only 200 feet. Its center lies twenty-five feet below the rest of the upper bituminous horizon. Its edges rise rapidly, however, and all of the upper bituminous coal forms with it a continuous seam. Because it lies below the rest of the seam and is of better quality, it is often regarded as a distinct seam. The coal in the upper horizon outside of the Big coal varies in thickness from three feet to five feet. It is generally inferior in quality and some of it is of value only as steam coal. It lies fifty feet below the prairie level, is horizontal in position

and free from fault. The Big coal ranks with the best coal produced in the county.

The Coalville basin seems to be part of the trough of an ancient river. The Big coal was formed in the stream channel, while the rest of the seam represents the bottom lands. The Big coal is too pure to admit the belief that water was flowing through the channel when the coal was deposited, and that the vegetable matter was drift material. The fact that as yet it has not been possible to connect the tortuous sections of the Big coal, also leads to the belief that the hollow in which the Big coal lies represents portions of a deserted channel, which in places was

FIG. [illegible]. Sandstone bluffs on the Des Moines river in central Webster county.

filled in and consequently is at times barren. The *Big* coal has an excellent shale roof and is worked very economically.

The next seam is known as the Colburn. It is found only along the river and near the mouth of Holaday creek, and where the lower or cannel coal is present it is lacking altogether. It is

rarely more than two feet in thickness and usually appears as two seams slightly separated by a layer of shale. The shale is so thin, however, that the two seams are mined together. The Colburn seam is not confined to the Coalville region, but from Holaday creek follows the river north to a point two miles above Fort Dodge. It will be described later in connection with the coal about Fort Dodge. At Holaday creek it lies twenty-five feet above the water of the creek and fifty feet below low water level in the river.

The cannel coal forms the lowest seam in the Coalville region. Its edges rise above the water of the river eighteen or twenty feet, but in the center, as shown at the Collins mine, it is on the level of the river water, while across the river at this point it is ten feet below water level. Its cross-section as shown on the river then, shows that it is like a saucer which is tilted slightly to the west. All of the cannel coal in the region belongs to this seam. On account of the difference in the position of the seam at various points, two and even three seams are sometimes reported. The cannel coal is found in sections 5, 7, 8 and 17 of Tp. 89 N., R. XXVIII W. These sections belong to Pleasant Valley and Otho townships. The exact extent of the seam cannot be stated, but as far as can be determined it is indicated in figure 8.

The following records of prospect holes sunk in Douglas township, section 8, Sw. ¼, indicate fairly the nature of the strata just above and below the upper bituminous coal*. These holes were sunk in the river slope, forty feet below prairie level.

		FEET.	INCHES.
5.	Soil and drift	24	
4.	Shale	9	6
3.	Coal	3	6
2.	Fire clay	1	6
1.	Sandstone	4	
4.	Soil and drift	24	6
3.	Shale	5	7
2.	Coal	3	7
1.	Black jack	1	

Coal in the vicinity of Fort Dodge is practically limited to the

* Authority, Craig Coal Company.

Colburn vein. This vein is well shown at the pit of the Kime brickyard, where the following section is given:

		FEET.	INCHES.
12.	Drift and soil	3	
11.	Shale, black, bituminous	4	
10.	Coal	1	2
9.	Clay	3	3
8.	Coal		5
7.	Sandstone, soft		8
6.	Fire clay	5	
5.	Shale, dark colored, bituminous	1	4
4.	Shale, bituminous, fissile	1	2
3.	Shale, dark colored	2	
2.	Shale, light colored	2	4
1.	Shale, dark colored, exposed	10	

The Colburn seam about Fort Dodge lies just below the drift, in the upper part of the Coal Measures. If the seam is really continuous to Holiday creek, as is commonly thought, its elevation as compared with the water level of the river remains fairly constant while the Coal Measures thicken rapidly above it toward the south. Across the river from the Kime brickyard coal appears at a lower level. This is shown by the following section which is taken one mile below the Minneapolis and St. Louis station, on the railroad track, in section 29, Sw. 1/4, Cooper township:

		FEET.	INCHES.
8.	Limestone, argillaceous, a single solid layer	1	6
7.	Coal		10
6.	Shale and clay	3	
5.	Impure coal	1	
4.	Carbonaceous shale	1	6
3.	Coal, fair quality	1	6
2.	Sandy shale, yellow (level of railroad track)	4	
1.	Shale, nearly covered with talus to water level	25	

In this section numbers three, four and five probably represent the Colburn vein. In the old mines above Fort Dodge the Colburn vein has been of considerable economic importance. Just above "the slide" in Douglas township, section 7, Sw. 1/4, on the west bank of the river the following section is given:

		FEET.
5.	Drift	8
4.	Argillaceous limestone, single heavy layer	2
3.	Coal	2
2.	Shale, fissile, very bituminous	44
1.	Sandstone, red and white, with fossils of coal plants—to water	6

At the old mines one-fourth mile below this point there are two coal horizons, one corresponding to the coal in the sections already given which lies directly under the limestone, while the other, which is a few feet lower, is probably the Colburn vein. It shows:

		FEET.	INCHES.
3.	Coal	2	
2.	Shale	2	
1.	Coal		6

These sections up the river taken together seem to be equivalent to the two sections just below Fort Dodge in the vicinity of the Kime brickyard.

The Limberg coal basin. At the mouth of Skiller creek in Dayton township a single seam has produced considerable coal. The mines are all located in the central part of section 16. This seam is about five feet above the level of the creek bed and is mined both by drifting into the banks of the creek and by shafts. The coal is from two feet to two feet four inches in thickness. It lies very unevenly, rising sometimes two feet in thirty. The roof is a tough gumbo through which pebbles are scattered. The coal at times suddenly gives out as though sharply cut off by stream erosion. There are no signs of faulting. Another coal seam is reported below the one now worked but no definite proof of its existence was obtainable. The seam encountered in Dayton township, section 18, which is shown in a section that will be quoted later on, is certainly lower than the one now worked at Limberg. The belief which seems to be common, that the coal horizons at Limberg are to be correlated with the seams at Lehigh, is not warranted. The various basins in the county are detached and cannot be worked into a common system.

The Tara coal basin is the only portion of the county away from the river at present producing coal. This basin includes

sections 33, 34 and 35, Douglas township, section 6, Elkhorn township, and probably adjacent territory that has not been prospected. The coal lies 130 feet below prairie level and the seam is from four to five feet thick in the Martins and Timmens mine on Ne. ¼, Sec. 6, Elkhorn township, in the Colford mine, Nw. ¼ of the same section, and in the Parel mine on the Scalley place, in Sw. ¼, Sec. 33, Douglas township. Borings in the adjacent territory indicate that the basin is of considerable extent, but do not show the thickness of coal that is found at the

FIG. 11. View showing natural arrangement of Carboniferous sandstone in Bone Yard Hollow four miles above Lehigh, Webster county

mines named. In Douglas township, Sec. 34, Se. ¼, five prospect holes were sunk and coal found in each case at about the same depth and under the same general condition. A record of one of these holes is given below:

		FEET.	INCHES.
11.	Soil and drift	75	
10.	Shale	3	
9.	Blue clay	8	4
8.	Coal	1	6
7.	Clay ironstone ?	2	10
6.	Fire clay	4	6
5.	Sandstone	8	9
4.	Red clay	3	2
3.	Sandstone	7	4
2.	Red clay	2	4
1.	Rock (undet.)	4	

In section 35, Douglas township, Sw. ¼, the following series was found:

		FEET.	INCHES.
15.	Soil	2	
14.	Drift	71	
13.	Red clay	4	
12.	Sand	1	6
11.	Sandstone	4	
10.	Shale	8	6
9.	Coal	2	3
8.	Sandstone	2	
7.	Shale	2	2
6.	Coal		6
5.	Fire clay	3	3
4.	Shale	2	1
3.	Coal	2	2
2.	Fire clay	8	9
1.	Red clay	21	6

There is no reason for believing that other coal basins may not be found in the county. Prospectors whose experience deserves respect do not think that extensive basins will be found away from the river. It is hardly probable that new seams will be found on the river. The Tara basin, however, is of sufficient importance to justify prospecting away from the Des Moines. Two miles east of Dayton, in Dayton township, Sec. 18, Nw. ¼, the Craig Coal company reports the following section:

		Feet	Inches
36.	Gravel	8	
35.	Yellow clay	13	4
34.	Sand	1	8
33.	Clay and sand	6	8
32.	Clay	11	
31.	Clay and sand	8	11
30.	Sandstone	[illegible]	[illegible]
29.	Clay		11
28.	Sand		1
27.	Clay	3	7
26.	Sandstone		7
25.	Clay		[illegible]
24.	Sandstone	4	1
23.	Clay		3
22.	Sandstone		1
21.	Clay		[illegible]
20.	Sandstone	2	[illegible]
19.	Clay	2	
18.	Sandstone	11	4
17.	Gray shale	[illegible]	
16.	Sandstone	4	[illegible]
15.	Shale	[illegible]	
14.	Rock (under...)		[illegible]
13.	Gray shale	[illegible]	4
12.	Black shale		[illegible]
11.	Rock (under...)	[illegible]	[illegible]
10.	Gray shale	[illegible]	[illegible]
9.	Hard rock (under...)	[illegible]	
8.	White clay		[illegible]
7.	Hard shale		
6.	Gray shale		
5.	Gray shale	[illegible]	[illegible]
4.	Black shale		[illegible]
3.	Coal		[illegible]
2.	Fire clay		
1.	Rock (under...)		

One mile northeast of [illegible] the [illegible] Coal Company obtained the following section:

		Feet	Inches
[illegible]	Surface	[illegible]	
[illegible]	[illegible] clay	[illegible]	
[illegible]	Sand		
[illegible]	Yellow clay		
[illegible]	Gravel		
[illegible]	Gray clay		

		FEET.	INCHES.
17.	Blue clay	8	8
16.	Yellow clay	5	4
15.	Blue clay	10	10
14.	Sand	11	5
13.	Clay	17	10
12.	Sand	1	
11.	Clay	20	4
10.	Sand		11
9.	Clay	1	6
8.	Shale	1	10
7.	Coal	3	6
6.	Fire clay	1	
5.	Shale	4	9
4.	Rock (undet.)	8	11
3.	Shale	1	7
2.	Shale and black jack	41	9
1.	Coal	4	

These records indicate that there is considerable coal in the vicinity of Dayton and the region at some time may become productive.

In the bed of the Boone river, just across the line in Hamilton county, two coal seams about ten inches thick may be seen. These seams probably extend into Webster county.

Coal Measure Sandstones in the Northern Part of the County.—Along the river in sections 13 and 24, Badger township, sandstone is exposed which probably belongs to the Coal Measures. It lies directly on the Saint Louis limestone and at certain places the line of unconformity between them may be seen. In section 24 the limestone in the form of great blocks, irregular in shape, is cemented by the sandstone.

The following section is found on the east bank of the river a little below the mouth of Deer creek in Badger township, Sec. 24, Nw. ¼:

		FEET.	INCHES.
6.	Drift	3	
5.	Sandstone, soft, calcareous	5	
4.	Shale		2
3.	Sandstone full of small flint and quartz fragments	6	
2.	Sandstone, cross-bedded, white, calcareous	1	
1.	Sandstone, ferruginous, with small concretions, to water	3	

The sandstone along this portion of the river is more definitely jointed than any seen in the county. This jointing shows well in an exposure one mile south of the county line on the east side of the river. The exposure is one-fourth of a mile back from the river on the edge of the second bench; the section reveals:

		FEET.
2.	Sandstone, disintegrated	6
1.	Sandstone, massive, regularly and conspicuously jointed, the joints running north-south and five to six feet apart. Stone in layers 6 to 15 feet thick, moderately hard	6

A distinct unconformity between this sandstone and the Saint Louis limestone which underlies it excludes the idea that it may be merely a thickening of the upper sandy layers of the Saint Louis formation. It may possibly be the sandstone which occurs above the gypsum. It is much more reasonable, however, to associate it with the Coal Measure sandstone which it more closely resembles and which is known to occur both north and south of these exposures.

In a ravine on the east side of the river just below Badger bridge sandstone forms a mural escarpment twenty feet high for 200 yards. In many ways it resembles the Coal Measure sandstone in the southern part of the county; it is yellow and cross-bedded, but it lacks fossils.

PERMIAN.

GYPSUM AND ASSOCIATED DEPOSITS.

Directly on the Saint Louis limestone or on the Coal Measure shales, in the central part of the county, lies the gypsum. Above it and associated with it are thin sandstone layers and shale, while below it and evidently of the same age is a layer of clay which on the average is four feet thick.

Except along the Des Moines river and tributary creeks the gypsum is wholly covered by drift. Away from the streams, wells and a limited number of prospect holes furnish the only data for determining the gypsum area and by these means it is impossible to decide with great definiteness the extent of underlying formations.

Natural exposures of gypsum may be seen at intervals along the river from the mouth of Soldier creek to one mile north of Coalville, and along Soldier and Two Mile creeks. Of these exposures the following are selected as typical:

Section at "the slide," on west bank of river, just opposite Blandon's mill.

		FEET.
7.	Drift, yellow, unleached, with many limestone pebbles	35
6.	Drift, blue gray, unleached, with many limestone pebbles, not sharply separated from above	20
5.	Drift, yellow, somewhat darker than 7, unleached, with many limestone pebbles	10
4.	Drift, blue gray, unleached	30
3.	Gypsum, badly weathered, exposed	10
2.	Limestone containing *Orbiculoidea nitida*, Orbiculoidea, species larger than the preceding, *Productus muricatus*, *Spirifer rockymontana*, a Pelecypod like an Aviculopecten, and a species of Orthoceras. The stone is argillaceous and like the limestone which generally caps the Coal Measures in Webster county	2
1.	Coal Measure shales, poorly exposed on account of the hillside wash	60

Exposure on Two Mile creek in Gypsum Hollow, at quarry of Lower Plaster mill.

		FEET.
5.	Drift, yellow, unleached, oxidized very moderately at surface and along joints, abounding in limestone pebbles, containing at one point a pocket 12 feet long and one foot thick of stratified sand in the shape of crescent	30
4.	Red sandy shale	0-4
3.	Gypsum, massive, in places moderately folded, in layers from six inches to two feet, laminæ averaging three-fourths of an inch, alternating in color, gray and white	20
2.	Fire clay, thickness undetermined.	
1.	Shale and sandstone (passed through in drilling well at lower mill of the Plaster Company)	100

Along the river above the Minneapolis & St. Paul railroad tracks the gypsum appears for 500 feet, in section 32, Cooper township.

Exposures along Soldier Creek.—In following Soldier creek towards its mouth nothing but drift was seen above section 17, Cooper township, Ne. ¼. Here, in cuttings along the Minneapolis and St. Louis track, which follows the creek bed from this point to Fort Dodge, red sandy shales appear. A little farther down, in the Sw. ¼ of the same section, the railroad in grading its road bed has cut through these shales exposing above them four feet of firm calcareous sandstone upon which rest thirty feet of drift. On the road leading to the cemetery much grading has been done to bring the road bed down to the valley of Soldier creek. In this cutting the following section is given:

	FEET.
2. Drift, fresh looking, with limestone pebples unleached	15
1. Shale, red, sandy, somewhat disintegrated.	6

Two hundred yards farther down the creek, just south of the cemetery, the first gypsum on the creek appears. A ledge ten feet high, heavily bedded, rises from the water's edge. Along the stream near this point Coal Measure shales are exposed and without doubt underlie the gypsum at this exposure.

On going down the creek 200 yards farther, in Cooper township, Sec. 17, Sw. ¼, one of the best exposures on the creek may be seen:

	FEET.
3. Drift, yellow, unleached	10
2. Red, sandy, calcareous shales—with layers of pure sand usually white, from ½ inch to a foot in thickness	30
1. Gypsum, massive to water's edge	7

One hundred yards farther down the stream, at the water level and for three feet above it, the Saint Louis limestone is exposed, which in turn within another 100 yards gives place to shale. This change at water level from gypsum to Saint Louis limestone, and from limestone to Coal Measure shale, is unusual; but, as has already been explained, it simply illustrates the unevenness of the surface of both limestone and Coal Measures.

The exposure at what was formerly known as Kohl's brewery, near the mouth of Soldier creek and within the Fort Dodge city

limits, has long been regarded as typical for the gypsum and associated red shale.

		FEET.
9.	Gravel, fresh, clean, well water-worn, containing much limestone	5
8.	Drift, slightly unoxidized, unleached	28
7.	Gravel, rusted, many decayed fragments, showing only at certain points along bluff	3
6.	Sandstone, soft, friable, buff colored, though at points not far away it is white and heavily bedded	5
5.	Shales, argillaceous, sandy layers alternating	5
4.	Sandstone, buff, friable	2
3.	Shale, gray	2
2.	Thin bands of gypsum and shale	7
1.	Gypsum, massive (exposed)	11

FIG. 12. Cross-section east and west through the gypsum area, illustrating unconformities between the Saint Louis limestone, the Coal Measures, and the gypsum. St. L. Saint Louis limestone. C. M. Coal Measures. G. Gypsum. D. Drift.

Section in the pit of the Fort Dodge Clay Works

		FEET.
3.	Drift, yellow, unleached, lower part a little darker than the upper	35
2.	Red sandy shale with occasional thin bands of sandstone	10
1.	Gray Coal Measure shales, often containing fossils of ferns and lepidodendrons. A few iron nodules present, and crystals of selenite. Separated from red shales above by sharp line of unconformity. Along the line of separation there is a layer of gumbo, one foot thick	30

No. 2 includes the red shales found in so many places above the gypsum. These red sandy shales are so characteristic and are associated so conformably with the gypsum that they may safely be regarded as of the same age as the gypsum. The occurrence of the light colored, calcareous sandstone free from fossils with these red shales is also significant. In a ravine running back from the North Lizard near the railroad bridge in Douglas township, section 8, Nw. ¼, the following section is given:

		FEET.
4.	Drift	10
3.	Gravel and bowlders	3
2.	Red sandy shales	10
1.	Sandstone dipping 10 degrees to the east, cross-bedded, in places fissile, often uncemented and appearing as sand, white or yellow, without fossils, conformable with 2	10

Keyes associated the sandstones and shales in this exposure with those which overlie the gypsum and this is apparently their proper place. There can be no doubt that the red shales of the Fort Dodge Clay Works, both in the south end of their old pit and in their new pit on the left bank of Lizard, belong to the gypsum series. The unconformity between the red shales and Coal Measure shales is distinct. The presence of sandstone with both of these shales renders more difficult the proper correlation of certain sandstones in the northern part of the county. These

FIG. 18. Exposure of gypsum on Soldier creek.

sandstones are reported by well drillers, and some apparently belong to the Coal Measures while others may be associated with

the gypsum. The last statement applies to those sandstones which are said to occur with shales of a deep red color or "ocher."

To determine the extent of the gypsum where there are no natural exposures is a difficult problem. The width of the deposit north and south is probably given accurately by the exposures along the Des Moines river. Its length or extent east and west must be determined by borings passing through the drift, which here averages eighty feet in thickness. Reference to the maps accompanying this report will show that the wells in the following table, in which gypsum was found, lie in a rather definite zone.

WELL DATA FOR CENTRAL AND NORTHERN WEBSTER COUNTY.

TOWNSHIP.	SECTION.	AUTHORITY.	DEPTH IN FEET	STRATA PASSED THROUGH. THICKNESS IN FEET.
Newark	Sec. 27, Sw. ½	Schmaker	126	Drift and blue clay, below which was gypsum.
Newark	Creamery at Vincent.	Schmaker.	80	Drift, 66; gypsum, 14.
Newark	Sec. 32, Nw. ¼	J. J. Meyer	118	Wholly in drift.
Badger	Sec. 25, Nw. ¼	J. J. Meyer	130	Drift, 70; sandstone, 4; clay, 25; sandstone, 30.
Badger	Sec. 31, Sw. ¼	J. J. Meyer	96	Drift, 80; sandstone, 16
Badger	Sec. 31, Nw. ¼	J. J. Meyer	110	Wholly in drift.
Badger	Sec. 31, Sw. ¼	J. J. Meyer	......	Depth not known, entered sandstone under drift.
Badger	Sec. 29, Nw. ¼	J. J. Meyer	70	Drift, 68; sandstone, 72
Badger	Sec 22, Sw. ¼	J. J. Meyer	120	Drift, 100; sandstone 20.
Badger	Sec. 34 Sw. ¼	J. J. Meyer	125	Drift, 55; sandstone, 8; soft sandstone, 40; clay, 2; sandstone, 20.
Badger	Sec. 11, Sw. ¼	J. J. Meyer	120	Drift 19; sandstone, 30.
Badger	Sec. 14, W. ½	J. J. Meyer	140	Drift, 90; sandstone, 50.
Badger	Sec. 17, Sw. ¼	J. J. Meyer	100+	Drift, 100; entered sandstone.
Badger	Sec. 22, Nw. ¼	J. J. Meyer	144	Drift, 80; sandstone, 4; red clay, 60.
Badger	Sec. 20, Nw. ¼	J. J. Meyer	118	Drift 100; hard sandstone, 18.
Badger	Sec. 16, Sw. ¼	Lappint	108	Wholly in drift.
Badger	Sec. 33, Nw ¼	Lappint	70	Drift, 50; limestone, 20.
Badger	Sec. 33. Nw. ¼	Lappint	120	Wholly in drift.
Badger	Sec. 20, Sw. ¼	Lappint	113	Drift, 50; sandstone, 6; clay, 50; sandstone, 7
Badger	Sec. 20, Sw. ¼	Lappint	116	Drift, 60; sandstone, 6; clay, 20; limestone, 30.
Badger	Sec. 32, Se. ¼	Lappint	120	Drift, 80; red clay, 40; sandstone.
Badger	Sec. 33, Sw. ¼	Lappint	90+	Drift, 90; stopped in sandstone.
Badger	Sec. 34, Sw. ¼	Lappint	68	Drift, 50; sandstone, 1; limestone, 17.
Colfax	Sec. 18, Sw. ¼	Lappint	50	Drift, 49; enter gypsum 5 inches.
Colfax	Sec. 17, S. ½.	Lappint	158	Drift, 90; shale, 6 ; limestone.
Colfax	Sec. 8, Sw. ¼.	Lappint	83	Drift, 60; gypsum, 23.
Colfax	Sec. 9, Nw. ¼	J. J. Meyer	132	Drift, 125; sandstone, 7.
Colfax	Sec. 7, Nw. ¼	J. J. Meyer	106	Wholly in drift.
Cooper	Sec. 4, Ne. ¼	Lappint	67	Drift, 40; red clay, 20; limestone, 7.
Cooper	Sec. 9, Nw. ¼	Lappint	90	Drift, 85; limestone, 5.
Cooper	Sec. 12, W. ½	Lappint	75	Drift, 60; sandstone, 4; gypsum.
Cooper	Sec. 31, Ne ¼	Craig Coal Co	42	Drift, 26; gypsum, 16.
Cooper	Sec. 27, Sw. ¼	Lappint	125	Drift, 120; limestone, 5
Cooper	Sec. 23, Sw. ¼	Lappint	81	Drift, 70; sandstone, 2; gypsum, 9.
Cooper	Sec. 26, S. ½	Lappint	101	Drift, 100; limestone, 1.
Cooper	Sec. 26, Nw. ¼	Lappint	80	Drift, 60; gypsum, 20.
Cooper	Sec. 34, Sw. ¼	Lappint	72	Drift, 47; gypsum, 25.
Cooper	Sec. 28, Se. ¼	J. J. Meyer	68	Drift, 57; gypsum, 21.
Cooper	Sec. 8, Nw. ¼	J. J. Meyer	104	Drift, 70, sandstone.
Cooper	Sec. 16	J. J. Meyer	87	Drift, 75; sandstone, 4; clay, 4; sandstone, 4.
Cooper	Sec. 10, Nw. ¼	J. J. Meyer	100	Drift, 80; sandstone, 20.
Douglas	Sec. 36, Se. ¼	Craig Coal Co	109	Drift, 76; gypsum, 18.
Douglas	Sec. 11, Se. ¼	J. J. Meyer	150	Drift, 135; sand, 14.
Washington	Sec. 12, Ne. ¼	Lappint	95	Drift, 50; sandstone, 45.
Otho	Sec 7, center.	Keyes' report	....	Drift, 57; gypsum, [illegible].
Elkhorn	Sec. 25, Sw ¼	Lappint	70	Drift overlying sandstone.
Elkhorn	Sec 6, N. ½	Lappint	120	Drift and Coal Measures. No gypsum.
Clay	Sec. 8, Nw ¼	Rasmusson & Stone	296	Drift, shale and 50 feet of limestone.
Elkhorn*	Sec. 32, Se. ¼	Rasmusson & Stone	252	Shale and 12 feet of limestone.

* Other wells of which records were obtained in Elkhorn township, were shallow and did not go through the drift.

RECORDS OF PROSPECT HOLES.

The following records of prospect holes also throw light upon the extent and stratigraphic relationship of the gypsum.

Cooper township, Sec. 33, Ne. 1/4, near bottom of valley of Two Mile creek.*

		Feet.	Inches.
29.	Creek silt	6	
28.	Yellow clay	14	
27.	Red shale	6	
26.	Gypsum	16	10
25.	Fire clay	1	6
24.	White sandstone	2	
23.	Brown sandstone	1	
22.	Red clay	2	
21.	Yellow clay	2	4
20.	Shale	13	6
19.	Clay ironstone ?	1	
18.	Fire clay	3	1
17.	Shale	3	
16.	Coal	1	7
15.	Sandstone	3	
14.	Fire clay	2	2
13.	Shale and black jack		3
12.	Sandstone	1	
11.	Shale		7
10.	Fire clay	4	3
9.	Sandstone	1	
8.	Shale	4	
7.	Soft sandstone	2	
6.	Shale	4	
5.	Fire clay	1	6
4.	Shale	3	
3.	Soft sandstone	4	
2.	Shale		3
1.	Limestone		6
		100	6

Pleasant Valley township, Sec. 4, Se. 1/4*.

		Feet.	Inches.
9.	Soil	3	
8.	Yellow clay	16	
7.	Blue clay	30	
6.	Red shale	4	
5.	Shales	30	
4.	Rock (undet.)	1	10
3.	Shale	9	
2.	Coal	2	7
1.	Black jack	..	8

* Authority, Craig Coal Company.

On the same quarter section:

		Feet.	Inches.
6.	Soil	2	
5.	Yellow clay	17	
4.	Blue clay	25	6
3.	Red shale	2	6
2.	Gypsum	12	
1.	Shale	5	6

Douglas township, Sec. 36, Se. 1/4 (on what is known as the Bassett farm).

		Feet.	Inches.
15.	Soil	2	
14.	Yellow clay	8	
13.	Blue clay and sand	36	
12.	Red sandy shale	30	
11.	Gypsum	1	
9.	Yellow shale		7
8.	Gypsum	17	7
7.	Shale	15	6
6.	Rock (undet.)	1	3
5.	Sandstone		6
4.	Coal		5
3.	Fire clay	5	1
2.	Shale	1	
1.	Brown sandstone	1	6
		119	9

Well on the Webster County Poor Farm, Elkhorn township, Sec. 3, Sw. 1/4.

		Feet.	Inches.
23.	Soil	2	
22.	Yellow clay	13	
21.	Blue clay	47	
20.	Sand	1	6
19.	Red shale	19	4
18.	Gypsum	17	
17.	Blue shale	6	2
16.	Limestone	2	
15.	Coal		9
14.	Fire clay	1	6
13.	Shale, light colored	1	4
12.	Coal	1	3
11.	Sandstone	4	
10.	Black shale	4	2
9.	Coal		3
8.	Fire clay	1	

		FEET.	INCHES.
7.	Sandstone, white	4	6
6.	Shale, with limestone bands	34	6
5.	Shale, light colored	5	
4.	Shale, blue	4	
3.	Calcareous shale	6	5
2.	Shale, blue	21	2
1.	Limestone (penetrated)	40	

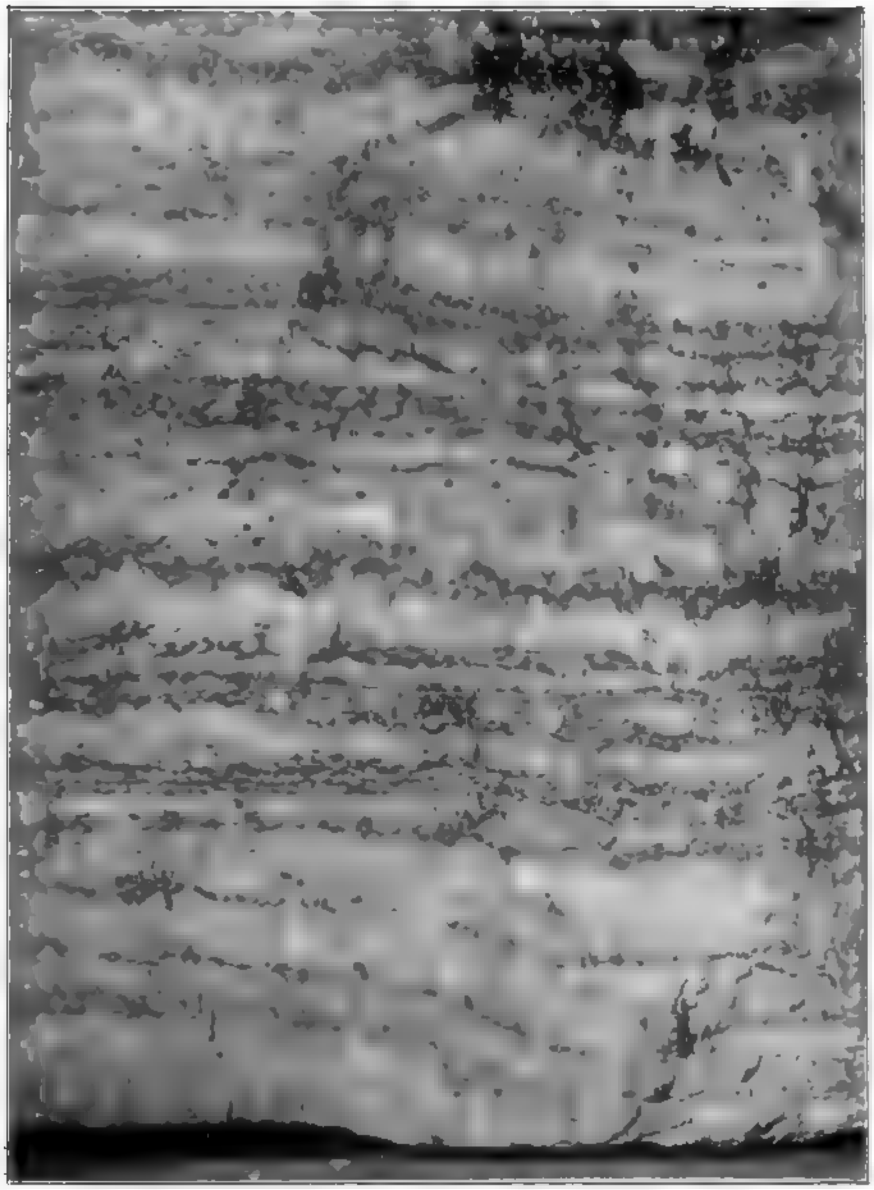
On the Sw. 1/4 of Sec. 6, Otho township, on which are located the mines that supply the Duncomb Plaster Mills, ten prospect holes gave the following records:

No. 1. 46 feet all in drift.
No. 2. 50 feet in drift and shale, 10 feet gypsum.
No. 3. 45 feet in drift and shale, 15 feet gypsum.
No. 4. 50 feet in drift and shale, 7 feet gypsum.
No. 5. 50 feet in drift and shale, 4 feet gypsum.
No. 6. 41 feet in drift and shale, 11 feet gypsum.
No. 7. (In a hollow) 6 feet of drift, 11 feet gypsum.
No. 8. 38 feet drift and shale, 6½ feet gypsum.
No. 9. 54 feet drift and shale, 12 feet gypsum.
No. 10. 45 feet drift and shale, 20 feet gypsum.

At the Mineral City Plaster Mill, in Cooper township, Sec. 34, Nw. 1/4, three prospect holes, 58, 70 and 74½ feet deep, gave sixteen to eighteen feet of gypsum, covered by red, sandy shale.

The Region in which Gypsum Underlies the Drift.—The well data and records of prospect holes neither positively confirm nor deny the suggestion of Keyes that the gypsum extends on from the Fort Dodge region through the southwestern part of the county and connects with the chalk deposits that are found near Auburn in the southeast corner of Sac county*. In the southwestern part of the county most of the wells do not go through the drift and little positive data in regard to the formations under the drift were attainable. Gypsum was not definitely reported by any well driller farther west than the Bassett and the Poor farms, two miles west of the river. Evidences of gypsum as far west as Moorland and Callender are too uncertain to make it wise to extend the gypsum area to those towns. A prospect hole drilled for F. J. Deischmidt just east of Moorland by the Jasper County Coal Company in search of coal, is said to have pene-

* Iowa Geol. Surv., Vol. III, p. 285.



Structure of the gypsum.

trated gypsum. The parties who possessed primary knowledge of this prospect hole have died and it is impossible to corroborate the report. The owner of the land, however, is positive that eleven feet of good gypsum was found and it is fair to include this region in the possible gypsum area, as is done on the accompanying map. North and east the gypsum area may now be extended beyond the limit which was definitely known when Keyes made his report. At Vincent gypsum was reported by those who drilled the creamery well. A number of reliable persons examined the material brought up by the bucket and pronounced it gypsum. In order to verify as far as possible these statements water from this well, which was said to stop just below the gypsum, was analyzed with these results:

Calcium oxide	[illegible]26	pts. per million
Sulphur trioxide	[illegible]	"
Equal to calcium sulphate	[illegible]	

The high percentage of calcium sulphate, one part in two thousand, would indicate the existence of gypsum in the neighborhood.

The geological map accompanying this report indicates localities in which gypsum certainly exists and suggests a larger area in which gypsum may be found.

NATURE OF THE GYPSUM BEDS.

All of the gypsum in Webster county, excepting the scattered crystals of selenite in the coal measure shales, is regularly stratified in heavy layers which are [illegible] less than six inches thick, commonly twelve inches [illegible], attaining [illegible] maximum thickness of two feet. The [illegible] are separated by [illegible] of clay. In thickness the deposit [illegible] to thirty feet. Instead of thinning out gradually [illegible] a considerable area, it seems to diminish but slightly [illegible] shale. At Kohl's brewery [illegible] of gypsum appear while half a mile [illegible] Dodge Brick and [illegible] shales are found. [illegible] the laminæ alternate [illegible]

gypsum is remarkably pure calcium sulphate ($CaSO_4+2H_2O$) The lower layers, generally the lower three feet, are not as pure as the upper and are not used in the manufacture of plaster. Even in these lower layers, however, the amount of the impurities is so small that they seem hardly sufficient to injure the plaster. An analysis* of the upper layers shows:

	PER CENT.
Calcium sulphate ($CaSO_4$)	78.44
Water of crystallization (calculated)	20.76
Insoluble matter (impurities)	.65

An analysis made by Professor J. B. Weems of gypsum taken from the lower, middle and upper part of those layers that are rejected in making plaster shows:

	PER CENT.
Silica (SiO_2)	1.92
Alumina (Al_2O_3)	1.00
Calcium sulphate ($CaSO_4$)	76.28
Water†	20.72
Total	99.92

When made into plaster this lower layer while soft will not adhere to the lath satisfactorily. In the calcining kettles it sticks to the sides and so causes trouble. After hardening it is as firm and durable as the plaster made from the upper layers of gypsum.

The following divisions in the gypsum beds are commonly recognizd by the miners:

		FEET.
5.	Upper rock suitable for plaster varying in thickness on account of differences in loss due to preglacial erosion	3-12
4.	Six foot seam, the best of the plaster rock	6
3.	Hard ledge, not good for plaster	4
2.	Eighteen inch ledge not good for plaster	1½
1.	Bottom ledge, not good for plaster	5

The gypsum is crystalline throughout, the slender needle-like crystals being arranged at right angles to the planes of sedimentation. Though the gypsum is now well preserved by the thick mantle of drift that overlies it, at one time it formed the surface

* Analysis by G. E. Patrick. Iowa Geol. Surv., Vol. III, p. 291.
† With traces of magnesia and carbon dioxide.

Gypsum quarry face. Iowa Plaster Company, Fort Dodge.

rock and in consequence suffered considerably from erosion and solution. When the overlying drift is removed, the surface of the gypsum everywhere appears deeply trenched and worn. Some of the trenches cut half way through the entire deposit. At times the gypsum is wholly cut out and records of drillings at points wholly surrounded by gypsum show only gravel. Trenches are frequently encountered in mining the gypsum, when they cause considerable trouble. When exposed along ravines the gypsum is decayed on the surface to a depth of three or four inches. The deep trenches in the gypsum are probably due as much to the action of water as a solvent as to its power as an erosive agent. Wherever the gypsum has been exposed in ledges for a period of years, it is picturesquely grooved and fluted.

AGE OF THE GYPSUM AND ASSOCIATED DEPOSITS.

In considering the age of the gypsum the red shales which accompany it must be kept in mind for they are very closely associated, as shown by exposures along Soldier creek, where thin layers of gypsum are found in the shales. Wherever they were not removed by preglacial erosion these shales overlie the gypsum conformably. Their extent is greater than that of the gypsum and in the pit of the Fort Dodge Clay Works, as already described, they may be seen resting unconformably on the Coal Measures. In Douglas township, section 8, there is a good exposure of these red shales which is six miles northwest of any known gypsum. Their color is striking, often brilliant, and for this reason they have been used to some extent as a natural pigment.

The fact that the gypsum and the red shales lie unconformably on the Coal Measures is good ground for believing that if they belong to the Paleozoic era they were formed near its close, during the Permian. The Permian beds of Kansas, Indian Territory and Texas, which contain quantities of gypsum, are so highly and so characteristically colored that they are known as the "red beds." These red beds like the red shales and gypsum of Iowa are nearly destitute of fossils, due probably to the fact that the climatic conditions favoring deposition of gypsum were hostile to organic life. Aridity is the climatic characteristic most essential for great deposits of gypsum, and the redness of the

the gypsum. The last statement applies to those sandstones which are said to occur with shales of a deep red color or "ocher."

To determine the extent of the gypsum where there are no natural exposures is a difficult problem. The width of the deposit north and south is probably given accurately by the exposures along the Des Moines river. Its length or extent east and west must be determined by borings passing through the drift, which here averages eighty feet in thickness. Reference to the maps accompanying this report will show that the wells in the following table, in which gypsum was found, lie in a rather definite zone.

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Newark........	Sec. 32, Nw. ¼	J. J. Meyer..........	118	Wholly in drift.
Badger	Sec. 25, Nw. ¼......	J. J. Meyer	130	Drift, 70; sandstone, 4; clay, 25; sandstone, 30.
Badger....	Sec. 31, Sw. ¼.......	J. J. Meyer	96	Drift, 80; sandstone, 16.
Badger	Sec. 31, Nw. ¼.....	J. J. Meyer..........	110	Wholly in drift.
Badger....	Sec. 31, Sw. ¼	J. J. Meyer..........	....	Depth not known, entered sandstone under drift.
Badger....	Sec. 29, Nw. ¼......	J. J. Meyer	70	Drift, 68; sandstone, 72
Badger....	Sec 22, Sw. ¼	J. J. Meyer..........	120	Drift, 100; sandstone 20.
Badger....	Sec. 34. Sw. ¼........	J. J. Meyer..........	125	Drift, 55; sandstone, 8; soft sandstone, 40; clay, 2; sandstone, 20.
Badger....	Sec. 11, Sw. ¼.......	J. J. Meyer..........	120	Drift 19; sandstone, 30.
Badger....	Sec. 14, W. ½.......	J. J. Meyer	140	Drift, 90; sandstone, 50.
Badger	Sec. 17, Sw. ¼.......	J. J. Meyer..........	100+	Drift, 00; entered sandstone.
Badger....	Sec. 22, Nw. ¼.....	J. J. Meyer...	144	Drift, 80; sandstone, 4; red clay, 60.
Badger....	Sec. 20, Nw. ¼.......	J. J. Meyer.	118	Drift. 100; hard sandstone, 18.
Badger....	Sec. 16, Sw. ¼.......	Lappint......	108	Wholly in drift.
Badger....	Sec. 33, Nw ¼.....	Lappint.....	70	Drift, 50; limestone, 20.
Badger....	Sec. 33. Nw. ¼	Lappint	120	Wholly in drift.
Badger....	Sec. 20, Sw. ¼......	Lappint	113	Drift, 50; sandstone, 6; clay, 50; sandstone, 7
Badger....	Sec. 20, Sw. ¼.......	Lappint	116	Drift, 60; sandstone, 6; clay, 20; limestone, 30.
Badger.... ...	Sec. 32, Se. ¼	Lappint	120	Drift, 80; red clay, 40; sandstone.
Badger...... ...	Sec. 33, Sw. ¼	Lappint......	90+	Drift, 90; stopped in sandstone.
Badger	Sec. 34, Sw. ¼	Lappint.....	68	Drift, 50; sandstone, 1; limestone, 17.
Colfax	Sec. 18, Sw. ¼	Lappint	50	Drift, 49; enter gypsum 5 inches.
Colfax	Sec. 17, S. ½.	Lappint.....	158	Drift, 90; shale, 6 ; limestone.
Colfax	Sec. 8, Sw. ¼.	Lappint	83	Drift, 60; gypsum, 23.
Colfax	Sec. 9, Nw. ¼.... .	J. J. Meyer..........	132	Drift, 125; sandstone, 7.
Colfax	Sec. 7, Nw. ¼.......	J. J. Meyer.........	106	Wholly in drift.
Cooper	Sec. 4, Ne. ¼.......	Lappint.....	67	Drift, 40; red clay, 20; limestone, 7.
Cooper....	Sec. 9. Nw. ¼.......	Lappint	90	Drift, 85; limestone, 5.
Cooper....	Sec. 12, W. ½.......	Lappint	75	Drift, 60; sandstone, 4; gypsum.
Cooper.... ...	Sec. 33, Ne ¼........	Craig Coal Co	42	Drift, 26; gypsum, 16.
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Cooper	Sec. 23, Sw. ¼.......	Lappint	81	Drift, 70; sandstone, 2: gypsum, 9.
Cooper	Sec. 26, S. ½	Lappint	101	Drift, 100; limestone, 1.
Cooper....	Sec. 26, Nw. ¼......	Lappint	80	Drift, 60; gypsum, 20.
Cooper	Sec. 34, Sw. ¼	Lappint......	72	Drift, 47; gypsum, 25.
Cooper.... . ..	Sec. 28, Se. ¼.......	J. J. Meyer	68	Drift, 57; gypsum, 21.
Cooper....	Sec. 8, Nw. ¼.......	J. J. Meyer..........	70+	Drift, 70, sandstone.
Cooper....	Sec. 16	J. J. Meyer..........	87	Drift, 75; sandstone, 4; clay, 4; sandstone, 4.
Cooper...... ...	Sec. 10, Nw. ¼......	J. J. Meyer..........	100	Drift, 80; sandstone, 20.
Douglas	Sec. 36, Se. ¼.......	Craig Coal Co	109	Drift, 76; gypsum, 18.
Douglas	Sec. 11, Se. ¼	J. J. Meyer	150	Drift, 135; sand, 14.
Washington....	Sec. 12, Ne. ¼......	Lappint	95	Drift, 50; sandstone, 45.
Otho	Sec. 7, center.	Keyes' report	.... .	Drift, 57; gypsum, 1.
Elkhorn.......	Sec. 25, Sw ¼.......	Lappint.....	70	Drift overlying sandstone.
Elkhorn.	Sec. 6, N. ½	Lappint	120	Drift and Coal Measures. No gypsum.
Clay.........	Sec. 8, Nw ¼	Rasmusson & Stone..	296	Drift, shale and 50 feet of limestone.
Elkhorn*.....	Sec. 32, Se. ¼	Rasmusson & Stone.	252	Shale and 12 feet of limestone.

* Other wells of which records were obtained in Elkhorn township, were shallow and did not go through the drift.

RECORDS OF PROSPECT HOLES.

The following records of prospect holes also throw light upon the extent and stratigraphic relationship of the gypsum.

Cooper township, Sec. 33, Ne. 1/4, near bottom of valley of Two Mile creek.*

		FEET.	INCHES.
29.	Creek silt	6	
28.	Yellow clay	14	
27.	Red shale	6	
26.	Gypsum	16	10
25.	Fire clay	1	6
24.	White sandstone	2	
23.	Brown sandstone	1	
22.	Red clay	2	
21.	Yellow clay	2	4
20.	Shale	13	6
19.	Clay ironstone ?	1	
18.	Fire clay	3	1
17.	Shale	3	
16.	Coal	1	7
15.	Sandstone	3	
14.	Fire clay	2	2
13.	Shale and black jack		3
12.	Sandstone	1	
11.	Shale		7
10.	Fire clay	4	3
9.	Sandstone	1	
8.	Shale	4	
7.	Soft sandstone	2	
6.	Shale	4	
5.	Fire clay	1	6
4.	Shale	3	
3.	Soft sandstone	4	
2.	Shale		3
1.	Limestone		6
		100	6

Pleasant Valley township, Sec. 4, Se. 1/4*.

		FEET.	INCHES.
9.	Soil	3	
8.	Yellow clay	16	
7.	Blue clay	30	
6.	Red shale	4	
5.	Shales	30	
4.	Rock (undet.)	1	10
3.	Shale	9	
2.	Coal	2	7
1.	Black jack		8

* Authority, Craig Coal Company.

On the same quarter section:

		Feet.	Inches.
6.	Soil	2	
5.	Yellow clay	17	
4.	Blue clay	25	6
3.	Red shale	2	6
2.	Gypsum	12	
1.	Shale	5	6

Douglas township, Sec. 36, Se. 1/4 (on what is known as the Bassett farm).

		Feet.	Inches.
15.	Soil	2	
14.	Yellow clay	8	
13.	Blue clay and sand	36	
12.	Red sandy shale	30	
11.	Gypsum	1	
9.	Yellow shale		7
8.	Gypsum	17	7
7.	Shale	15	6
6.	Rock (undet.)	1	3
5.	Sandstone		6
4.	Coal		5
3.	Fire clay	5	1
2.	Shale	1	
1.	Brown sandstone	1	6
		119	9

Well on the Webster County Poor Farm, Elkhorn township, Sec. 3, Sw. 1/4.

		Feet.	Inches.
23.	Soil	2	
22.	Yellow clay	13	
21.	Blue clay	47	
20.	Sand	1	6
19.	Red shale	19	4
18.	Gypsum	17	
17.	Blue shale	6	2
16.	Limestone	2	
15.	Coal		9
14.	Fire clay	1	6
13.	Shale, light colored	1	4
12.	Coal	1	3
11.	Sandstone	4	
10.	Black shale	4	2
9.	Coal		3
8.	Fire clay	1	

		FEET.	INCHES.
7.	Sandstone, white	4	6
6.	Shale, with limestone bands	34	6
5.	Shale, light colored	5	
4.	Shale, blue	4	
3.	Calcareous shale	6	5
2.	Shale, blue	21	2
1.	Limestone (penetrated)	40	

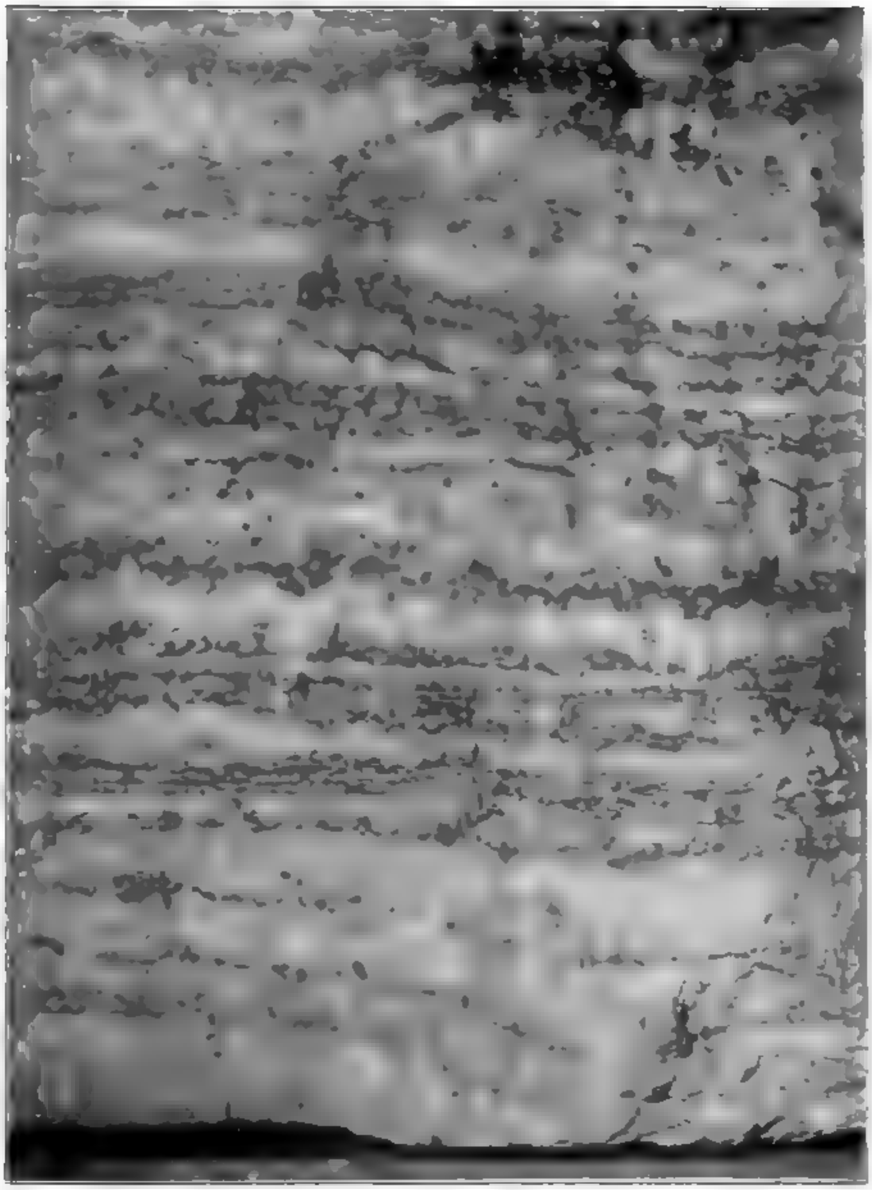
On the Sw. ¼ of Sec. 6, Otho township, on which are located the mines that supply the Duncomb Plaster Mills, ten prospect holes gave the following records:

No. 1. 46 feet all in drift.
No. 2. 50 feet in drift and shale, 10 feet gypsum.
No. 3. 45 feet in drift and shale, 15 feet gypsum.
No. 4. 50 feet in drift and shale, 7 feet gypsum.
No. 5. 50 feet in drift and shale, 4 feet gypsum.
No. 6. 41 feet in drift and shale, 11 feet gypsum.
No. 7. (In a hollow) 6 feet of drift, 11 feet gypsum.
No. 8. 38 feet drift and shale, 6½ feet gypsum.
No. 9. 54 feet drift and shale, 12 feet gypsum.
No. 10. 45 feet drift and shale, 20 feet gypsum.

At the Mineral City Plaster Mill, in Cooper township, Sec. 34, Nw. ¼, three prospect holes, 58, 70 and 74½ feet deep, gave sixteen to eighteen feet of gypsum, covered by red, sandy shale.

The Region in which Gypsum Underlies the Drift.—The well data and records of prospect holes neither positively confirm nor deny the suggestion of Keyes that the gypsum extends on from the Fort Dodge region through the southwestern part of the county and connects with the chalk deposits that are found near Auburn in the southeast corner of Sac county*. In the southwestern part of the county most of the wells do not go through the drift and little positive data in regard to the formations under the drift were attainable. Gypsum was not definitely reported by any well driller farther west than the Bassett and the Poor farms, two miles west of the river. Evidences of gypsum as far west as Moorland and Callender are too uncertain to make it wise to extend the gypsum area to those towns. A prospect hole drilled for F. J. Deischmidt just east of Moorland by the Jasper County Coal Company in search of coal, is said to have pene-

* Iowa Geol. Surv., Vol. III, p. 285.



Structure of the gypsum.

trated gypsum. The parties who possessed primary knowledge of this prospect hole have died and it is impossible to corroborate the report. The owner of the land, however, is positive that eleven feet of good gypsum was found and it is fair to include this region in the possible gypsum area, as is done on the accompanying map. North and east the gypsum area may now be extended beyond the limit which was definitely known when Keyes made his report. At Vincent gypsum was reported by those who drilled the creamery well. A number of reliable persons examined the material brought up by the bucket and pronounced it gypsum. In order to verify as far as possible these statements water from this well, which was said to stop just below the gypsum, was analyzed with these results:

Calcium oxide	226	pts. per million
Sulphur trioxide	322.5	" "
Equal to calcium sulphate	548.5	

The high percentage of calcium sulphate, one part in two thousand, would indicate the existence of gypsum in the neighborhood.

The geological map accompanying this report indicates localities in which gypsum certainly exists and suggests a larger area in which gypsum may be found.

NATURE OF THE GYPSUM BEDS.

All of the gypsum in Webster county, excepting the scattered crystals of selenite in the Coal Measure shales, is regularly stratified in heavy layers which are rarely less than six inches thick, commonly twelve inches or more, attaining a maximum thickness of two feet. The layers are separated by traces of clay. In thickness the deposit varies from ten to thirty feet. Instead of thinning out gradually through a considerable area, it seems to diminish but slightly before it abruptly gives place to shale. At Kohl's brewery, for instance, ten feet of gypsum appear while half a mile farther north in the clay pit of the Fort Dodge Brick and Tile Company only drift and Coal Measure shales are found. Everywhere in the Webster county gypsum the laminæ alternate regularly in color, gray and white. The

gypsum is remarkably pure calcium sulphate ($CaSO_4+2 H_2O$) The lower layers, generally the lower three feet, are not as pure as the upper and are not used in the manufacture of plaster. Even in these lower layers, however, the amount of the impurities is so small that they seem hardly sufficient to injure the plaster. An analysis* of the upper layers shows:

	PER CENT.
Calcium sulphate ($CaSO_4$)	78.44
Water of crystallization (calculated)	20.76
Insoluble matter (impurities)	.65

An analysis made by Professor J. B. Weems of gypsum taken from the lower, middle and upper part of those layers that are rejected in making plaster shows:

	PER CENT.
Silica (SiO_2)	1.92
Alumina (Al_2O_3)	1.00
Calcium sulphate ($CaSO_4$)	76.28
Water†	20.72
Total	99.92

When made into plaster this lower layer while soft will not adhere to the lath satisfactorily. In the calcining kettles it sticks to the sides and so causes trouble. After hardening it is as firm and durable as the plaster made from the upper layers of gypsum.

The following divisions in the gypsum beds are commonly recognizd by the miners:

		FEET.
5.	Upper rock suitable for plaster varying in thickness on account of differences in loss due to preglacial erosion	3-12
4.	Six foot seam, the best of the plaster rock	6
3.	Hard ledge, not good for plaster	4
2.	Eighteen inch ledge not good for plaster	1½
1.	Bottom ledge, not good for plaster	5

The gypsum is crystalline throughout, the slender needle-like crystals being arranged at right angles to the planes of sedimentation. Though the gypsum is now well preserved by the thick mantle of drift that overlies it, at one time it formed the surface

* Analysis by G. E. Patrick. Iowa Geol. Surv., Vol. III, p. 291.
† With traces of magnesia and carbon dioxide.

Gypsum quarry face. Iowa Plaster Company, Fort Dodge.

rock and in consequence suffered considerably from erosion and solution. When the overlying drift is removed, the surface of the gypsum everywhere appears deeply trenched and worn. Some of the trenches cut half way through the entire deposit. At times the gypsum is wholly cut out and records of drillings at points wholly surrounded by gypsum show only gravel. Trenches are frequently encountered in mining the gypsum, when they cause considerable trouble. When exposed along ravines the gypsum is decayed on the surface to a depth of three or four inches. The deep trenches in the gypsum are probably due as much to the action of water as a solvent as to its power as an erosive agent. Wherever the gypsum has been exposed in ledges for a period of years, it is picturesquely grooved and fluted.

AGE OF THE GYPSUM AND ASSOCIATED DEPOSITS.

In considering the age of the gypsum the red shales which accompany it must be kept in mind for they are very closely associated, as shown by exposures along Soldier creek, where thin layers of gypsum are found in the shales. Wherever they were not removed by preglacial erosion these shales overlie the gypsum conformably. Their extent is greater than that of the gypsum and in the pit of the Fort Dodge Clay Works, as already described, they may be seen resting unconformably on the Coal Measures. In Douglas township, section 8, there is a good exposure of these red shales which is six miles northwest of any known gypsum. Their color is striking, often brilliant, and for this reason they have been used to some extent as a natural pigment.

The fact that the gypsum and the red shales lie unconformably on the Coal Measures is good ground for believing that if they belong to the Paleozoic era they were formed near its close, during the Permian. The Permian beds of Kansas, Indian Territory and Texas, which contain quantities of gypsum, are so highly and so characteristically colored that they are known as the "red beds." These red beds like the red shales and gypsum of Iowa are nearly destitute of fossils, due probably to the fact that the climatic conditions favoring deposition of gypsum were hostile to organic life. Aridity is the climatic characteristic most essential for great deposits of gypsum, and the redness of the

sandstones and shales usually accompanying gypsum deposits of all ages and localities may fairly be assumed to be an effect of climate, direct or indirect, on the iron content of the soil. All of these considerations, namely, the arid climate that prevailed during the Permian, shown by great gypsum deposits associated with red shales occurring in both Europe and America, and the striking resemblance which the series bears to the Permian only 300 miles to the west, carry great weight. The Iowa series might reasonably be interpreted as an outlier of the Permian of Kansas and Indian Territory. During the long interval between its deposition and that of the drift which now protects it erosion had an abundant opportunity to remove the Permian from the intervening territory. The gypsum was doubtless protected by heavy beds of the red shales, for had it been exposed long it must have yielded to the solvent and erosive action of water.

It is possible to refer the gypsum to the Triassic or to the Cretaceous. Like the Permian, the Triassic of the west is red and contains large deposits of gypsum, notably those of the Black Hills. Known outcrops of Triassic strata occur only far to the west of the area under consideration, much farther west than the most eastern exposures of recognized Permian in Kansas. While this fact favors a reference of the Iowa gypsum to the Permian rather than the Triassic, the fact that the Permian of Kansas rests conformably on the Coal Measures while the gypsum of Iowa does not, throws a certain amount of weight the other way.

The claims of the Cretaceous have been considered in previous reports on the region*. Reference to the geological map of Iowa shows that Cretaceous deposits are present throughout the greater part of northwestern Iowa and that they approach within thirty miles of Webster county, at Auburn in Sac county, where they appear as chalk. The Cretaceous in Iowa consists of sandstone of the Dakota stage, and shales, limestone and chalk of the Colorado stage. Sandstone, shales and limestone have yielded abundant fossils which definitely fix their age. Other things being equal, it would be somewhat more natural to regard the Webster county gypsum series as an outlier of the Creta-

* Iowa Geol. Surv., Vol. III, p. 293.

ceous than of the Permian which is farther away, yet the distance is not so great as to render a correlation with the Permian in any degree improbable if the preponderance of other evidence favors such a view. A review of Cretaceous climatic conditions is first of all necessary, for if aridity is a more striking characteristic of the Permian than of the Cretaceous, the Cretaceous age of the gypsum can hardly be established. The Dakota sandstone is at times red, but this color does not everywhere prevail and it does not characterize the Cretaceous shales and limestones in any degree. The Dakota sandstone abounds in fossils, as does the limestone of the Colorado stage, in which *Inoceramus labiatus* is found in great numbers. The Benton shales, while not so rich in fossils as the limestone, contain *Ostrea congesta*, *Prionocyclus wyomingensis* and other species, none of which are brackish water forms. They contain also some selenite, but in view of the fossil contents of the shales it is probable that the selenite was not formed by precipitation from concentrated brine at the time that the shales were laid down, but is due to subsequent chemical reaction in which sulphuric acid, generated perhaps from iron pyrites, converted part of the lime carbonate of the shales into the sulphate. In barrenness of fossils, in color and in association with gypsum the red shales which accompany the Iowa gypsum resemble the Permian of Kansas much more than they do the Cretaceous shales of Iowa. The presence of chalk in Sac county, close to what must have been the Cretaceous shore indicates that for a time sediments from land were at a minimum and organic sediments unmixed with land waste were able to accumulate near the shore. This would indicate an absence of the barren surface usually attending aridity, or the absence of elevation, or both, so that climatic conditions favoring deposits of gypsum are not implied by the chalk of the Cretaceous. Regions devoid of rainfall are characterized by windstorms of great violence capable of transporting much earthy material as dust and carrying it out to sea where it would ultimately be deposited. The arid regions of America are subject to brief but violent rain storms during which erosion is vigorous on the surface barren of vegetation. Low land surfaces covered with an abundant vegetation are most favorable for pure chemical and

organic accumulations in the neighboring seas. The great purity of many gypsum deposits presents a difficulty for this very reason, for the land must have been barren during the concentration of the sea water and conditions favorable for dust storms seem likely to have prevailed. Microscopic examination of the Iowa gypsum reveals particles of sand scattered through the gypsum, probably by wind, but the total amount is small, amounting to about one per cent of the whole.

The age of the great gypsum and salt deposits of the world is shown below:

FOREIGN.		AMERICAN.	
PLEISTOCENE AND RECENT.			
Caspian Sea and Asia.ic Lakes.	1.	Great Salt Lake.	
PLIOCENE.			
Transylvania, near Prague (salt).	2.		
Caspian sea in Karabhogas bay (salt and gypsum).	3.		
Austria at Wieliczka, Siebenbürgen (salt and gypsum).	4.		
MIOCENE.			
None.			
OLIGOCENE.			
Transylvania and Carpathian Mts. (gypsum and salt).	5.		
Germany, Sperenberg (gypsum).	6.		
France, Montmartre (gypsum).	7.		
EOCENE.			
None.			
CRETACEOUS.			
None.			
JURASSIC.			
None.			
TRIASSIC.			
Germany: Hanover, Austadt. Erfurt, Thuringia. Lothringer (gypsum and salt).	8.	Black Hills (gypsum).	10.
England: From Scotland to Devonshire (gypsum and salt).	9.		

FOREIGN.		AMERICAN.	

PERMIAN.

Germany:	11.	Iowa (gypsum).	
The Hartz (gypsum).		Texas gypsum).	13.
Stassfurt, Sperenberg (gypsum and salt.)		Kansas (salt and gypsum).	14.
South Tyrol (gypsum).		Oklahoma and Indian Territory.	
Russia (gypsum, salt).	12.	Black Hills, (gypsum).	15.

UPPER CARBONIFEROUS.

None.

LOWER CARBONIFEROUS.

		Lower Michigan (gypsum).	16.
		Nova Scotia (gypsum and salt).	17.
		Virginia (gypsum and salt).	18.
		Montana (gypsum).	19.

DEVONIAN.

None.

SILURIAN.

Russia, Baltic provinces(gypsum).	20.	New York (gypsum and salt).	21.
		Ohio (gypsum and salt).	22.
		Pennsylvania (gypsum).	23.
		Upper Michigan (gypsum).	24.

ORDOVICIAN.

None.

CAMBRIAN.

Punjab Salt Range, India.	25.		

1. Geikie Text Book of Geol., 3d Ed., pp. 737-739.
2. Geikie Text Book of Geol., p. 1018.
3. Geikie Text Book of Geol., 3d Ed., p. 1004
4. Credner Geologie, pp. 639-700.
5. Geikie Text Book of Geol., 3d Ed., p. 933.
6. Credner Geologie, p. 679.
7. Credner Geologie, p. 675.
8. Credner Geologie, p. 520.
9. Geikie Text Book of Geol., 3d Ed., p. 866.
10. U. S. Geol. Surv., Darton's report on Black Hills, 21st Ann. Rep., part IV.
11. Credner Geologie, pp. 503-511.
12. Geikie Text Book of Geol., 3d Ed., p. 853.
13. Third Ann. Rep. Texas Surv., p. 212.
14. University Geol. Surv. of Kansas, Vol. V.
15. U. S. Geol. Surv., Darton's report on Black Hills, 21st Ann. Rep., part IV.
16. Geol. Surv. Michigan, Vol. V, (1881-93), part II, pp. 14-30.
17. Mineral Resources, Canada, 1897, pp. 105-111.
18. Resources Southwestern Virginia. Boyd., 1875, pp. 260-304
19. U. S. Geol. Surv., Benton Folio, p. 6.
20. Geikie Text Book of Geol., 3d Ed., p. 789
21. New York Geol. Surv., Vol. III, No. 15, p. 550.
22. Geol. Surv. Ohio, Vol. VI, pp. 691-702.
23. Geol. Surv. Pennsylvania, Summary Final Reports, Vol. II, pp. 913-915.
24. Geol. Surv. Michigan, Vol. I 1869 73, part III, pp. 29-31.
25. Geikie Text Book of Geol., 3d Ed., pp. 737-739.

Climatic conditions in both hemispheres, therefore, seem to have been favorable for deposits of gypsum during the Permian, whereas if the Iowa gypsum were referred to the Cretaceous it would be the only gypsum deposit of economic importance in Europe or America assigned to this period of geological history. The gypsum may therefore be reasonably regarded as Permian, though the possibility of its being Triassic cannot be denied.

ORIGIN OF THE GYPSUM.

Gypsum deposits are generally ascribed to two causes: (1) the transformation of deposits already formed by various chemical reactions, and to precipitation from sea water, due primarily to concentration by evaporation, and (2) to reactions between the salts in solution.

The most frequent transformation of deposits already formed is the change of limestone ($CaCO_3$) into gypsum, ($CaSO_4 + 2\ H_2O$) through the agency of sulphuric acid, according to the equation $H_2SO_4 + CaCO_3 = CaSO_4 + CO_2 + H_2O$. The sulphuric acid may be generated by the oxidation of the sulphuretted hydrogen of sulphur springs or of volcanoes, or by the action of water on some sulphide ore like pyrites. The deposits which Dana attributes to the action of sulphuric acid generated from the sulphuretted hydrogen given off by sulphur springs in New York* are quite extensive. In certain instances the gypsum occurs in masses with irregular outline in limestone, and layers of shale in the limestone pass unaltered through the gypsum. In view of this evidence the gypsum must be regarded as derived from the limestone. Deposits of this sort are exceptional, however, and it is probable that most of the gypsum of New York had a different origin.

Insignificant gypsum deposits occur about the fumaroles of craters and lava streams in Hawaii where sulphurous acid (SO_2) is converted into sulphuric, and attacks rocks which contain lime. The frequent occurrence of small amounts of gypsum with hematite in the upper part of ore veins may be accounted for by the following reaction†, $Fe_2O_3(SO_3)_3 + 2CaCO_3$

* Dana, Manual of Geology, 4th Ed, p. 554.

† Beck Erzlagerstattenlehre, p. 393.

[illegible] form [illegible] gypsum [illegible]

[illegible] gypsum [illegible] sea water [illegible] Sea water contains [illegible] per cent of mineral matter, distributed as follows:

	Per cent
Chloride of sodium	[illegible]
Chloride of magnesium	[illegible]
Sulphate of magnesium	[illegible]
Sulphate of calcium (gypsum)	[illegible]
Sulphate of potassium	[illegible]
Carbonate of lime	[illegible]
Bromide of magnesium	[illegible]
Total	[illegible]

Gypsum is deposited from typical sea water when [illegible] per cent of the water has evaporated,* whereas [illegible] salt is not deposited until the bulk of the water is reduced more than [illegible] per cent. Gypsum deposits are more widespread than salt, but salt usually occurs in thicker beds. These facts taken with the relative amount of each salt in sea water and the amount of evaporation necessary for precipitation in each case, accord with the theory which regards the evaporation of sea water as the cause of most salt and gypsum deposits. It is evident that conditions allowing the 80 per cent of evaporation necessary for a gypsum deposit would occur more often than those giving rise to 90 per cent of evaporation and a deposit of rock salt. When the amount of evaporation necessary for a salt deposit took place, however, the high percentage of salt in the water would yield a stratum of notable thickness as compared with gypsum.

The accompanying diagram (Fig. 14) indicates the relation of deposition to density in the case of the salts common to sea water. The magnesium chloride alone is not actually precipi

* M. Dieulafait in Pop. Sci. Mon., Oct., 1892.

tated but remains in solution always under ordinary atmospheric conditions. It may be precipitated, however, with potassium chloride as carnallite. Three-fourths of the gypsum is deposited

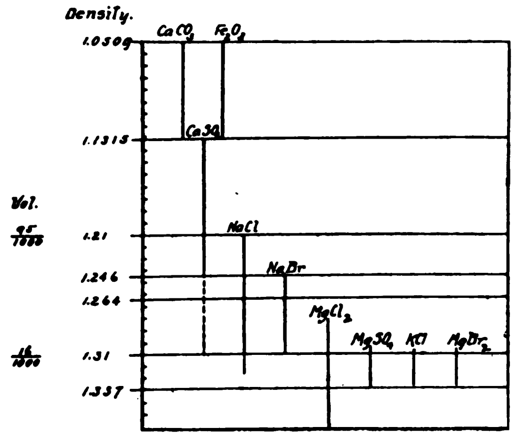


FIG. 14 Sketch showing the order of precipitation of salts from sea water, with increase in density due to evaporation.

between the densities of 1.1315 and 1.21, whereas the deposition of salt does not begin until the latter point is reached. The remaining one-fourth is precipitated with the salt, but constitutes so small a part of the whole that the commercial value of the salt is not appreciably lowered. The normal order of deposition on evaporation from sea water, beginning with the first which occurs, of course, at the bottom of the deposit, is:

1. Limestone with limonite, $CaCO_3$ and 2 Fe_2O_3 + 3 H_2O.
2. Gypsum Ca SO_4 + 2 H_2O.
3. Sodium chloride (common salt) Na Cl.
4. The bitter salt (in carnallite) KCl + $MgCl_2$ + 6 H_2O.

Practically this order is observed in the great salt deposits of Stassfurt, Germany.

While gypsum has been formed and is still forming in all of the ways described, most of these explanations are manifestly not adapted to the Webster county deposit. The definite lamination and layering of the gypsum indicate an aqueous origin. Pointing to the same conclusion is the fact that no limestones are associated with the gypsum which by alteration could yield gypsum. Salt may be regarded as absent from the Iowa gypsum area. If it existed it would probably have been detected in some

of the many wells and prospect holes. Its absence is not surprising for the degree of concentration necessary for a salt deposit may never have been reached, or the salt after having been deposited may have been removed by subsequent erosion and solution.

The great thickness of some occurrences of gypsum and salt must be considered in seeking to determine their origin. The combined series of Stassfurt amounts to more than 1,000 feet and at Sprenberg to more than 3,000 feet. To yield even fifteen feet of gypsum, the average thickness in the Iowa field, an immense amount of water must have been evaporated. A cubic foot of gypsum weighs 140 pounds and the amount of gypsum in a cubic foot of sea water today is three-fiftieths of one pound. The amount of water necessary to yield a cubic foot of gypsum then is 2,332.4 cubic feet. If the sides of the containing basin were vertical the depth of the water necessary to produce fifteen feet of gypsum must have been 34,986 feet. If the average thickness of the Iowa gypsum be taken as fifteen feet and the gypsum area seventy square miles in extent, the amount of sea water necessary to deposit it, assuming that its content of gypsum was the same as in sea water today, was sixty-eight trillions of cubic feet. If a basin twenty miles wide be assumed, with two shores sloping to a center at an angle of 10 degrees, the length of the basin which would contain this amount of water must have been twenty-six miles and the depth at the center more than 9,000 feet, diminishing uniformly in depth from the center. Such a trough manifestly never existed and the hypothesis that the gypsum was deposited in a detached arm of the ocean, unaided by considerable supplies of salt from rivers or from the main body of salt water, is untenable. There remain to be considered: 1. Arms of the sea which were at least part of the time connected with the ocean and which received more or less water from land; 2. Enclosed seas fed wholly by rivers and without outlet except by evaporation.

Taking up the second case first, it will be instructive to review the conditions actually existing in enclosed salt seas in Asia and America.

The nature of the salt deposits made in a lake not connected

with the ocean and without outlet, where evaporation is as great as or greater than inflow may vary as widely as do the relative proportion of salts in the inflowing streams. If the lake was at one time a part of the ocean this fact is of consequence in determining the nature of salt deposition. The variation in the nature and amount of salts carried in solution by different streams is a natural consequence of differences in mineral cons i tution of their drainage areas. In the Elbe and Thames chlorides predominate* (in the latter with gypsum) and the evaporation of these waters would give rise to lakes containing a large percentage of common salt. In the Seine sulphate of lime (gypsum) predominates, while the waters of the Rhine, Danube and Arr contain small amounts of chlorides and large percentages of sulphates of lime and magnesia. The Loire contains in 100,-000 parts 13.46 of solid matter of which 35 per cent is calcium carbonate, while two-thirds of the soluble salts are carbonate of soda. In nearly all rivers bicarbonate of soda is present in large quantities. The water of the river Jordan gives the following analysis:†

Sodium chloride (common salt)	.35
Magnesium chloride	.03
Calcium chloride	.07
Calcium sulphate (gypsum)	.04
Water	99.50

The waters of the Dead Sea are the result of concentration by evaporation of waters containing salt. Quoting Bischof‡: "In spring when the streams are turbid with the particles of carbonate of lime and clay, mere mechanical deposits take place for at this period, when large masses of water are carried into the Dead Sea, and the saline solution thereby diluted, while at the same time the evaporation is but slight, no common salt is deposited. During the ensuing warmer months the chemical deposition of common salt and carbonate of lime take place. Should the stream become turbid at this season in consequence of continued rain deposits are formed which contain a less amount of common salt. In this way there must arise a constant alternation of different irregular layers of greater or less thickness. All

* T. Sterry Hunt. Chemical and Geological Essays.
† Bischof. Vol. I, Chem. and Phys. Geology.
‡ Ibid, p. 397.

these layers must contain gypsum, since in a water which contains so much chloride of magnesium as is present in the Dead Sea, gypsum, as we shall subsequently see, is dissolved with difficulty, as is also shown by the small proportion in which this salt exists in that sea."

Lake Elton, a brine pool of the Russian steppes, may once have had an oceanic connection. If this is true the calcium carbonate and gypsum of the original sea water have been deposited, for the water now contains but small quantities of lime salts but chlorides of sodium and magnesium with sulphide of magnesium are present in abundance*. Bischof describes the lake as follows: "The Elton lake, whose greatest diameter is 20 and its smallest 16 versts, lies 19 feet below the level of the ocean. It has flat banks and may be waded through almost anywhere. On its margins and upon its bed there is almost everywhere crystalline salt. This forms layers from one to two inches in thickness which are separated from one another by layers of mud and earth. The streams which empty into it are eight in number. They all contain more or less salt, and consequently carry supplies of this substance into the lake. The most considerable among them is the Charisacha, which is also the only one which continues to flow during the whole year. In the loamy soil which surrounds the lake numerous small crystals of gypsum are imbedded." A deposit of salt is formed in this lake every summer, in the winter and spring the water is diluted by the rivers which are then copious and a layer of silt, probably carrying some gypsum is formed. The decrease or complete disappearance of $Ca\,SO_4$ from the water of Lake Elton into which it is being constantly conveyed by the Charisacha river, the waters of which have been analyzed, shows that the gypsum goes down with the salt.

Great Salt Lake in Utah furnishes an excellent example of salt deposits in a lake without oceanic connections. The present lake is but a remnant of the much larger Lake Bonneville, which was fresh and was drained by a stream flowing into the Snake river. Its present salinity is high, the specific gravity of the water being 1.1 + and its saline contents, varying with the seasons

* Analysis by Gobel, quoted by Bischof, Chem. and Phys. Geol. Vol. I, p. 404.

from 14 to 22 per cent, is distributed as follows, as shown in five analyses*:

Sodium chloride	90.7	79.1	65.9	81.3	80.5
Potassium chloride		....	14.1	....	....
Magnesium chloride	1.1	9.9	8.9	6.7	10.3
Sodium sulphate	8.2	6.2	8.1	8.5	5.4
Potassium sulphate		3.6	....	2.6	2.4
Calcium sulphate		.6	1.5	.9	1.4
Chlorine (in excess)		.6	1.5	....	....

In these analyses the absence or the very small content of calcium, both as sulphate and carbonate, is remarkable. Analyses of the fresh waters tributary to the lake show that the lake could accumulate its total content of calcium in eighteen years while the accumulation period for the chlorine would be 34,200 years.† Manifestly the lake is disposing of the calcium as fast as it is received. Deposits of tufa occur on the old Bonneville, Intermediate and Provo shore lines, on their weathered faces, and a few feet below their crests. It is absent in sheltered bays and most abundant on points that were especially exposed to wave action. Calcareous oolitic sands are now forming along certain parts of the shore of Salt Lake "between the delta of the Jordan and Black Rock, where it constitutes the material of a beach, and is drifted shoreward in dunes."‡ Of the three important fresh water tributaries of Great Salt Lake, the water of Utah Lake is characterized by sulphate of lime, over 60 per cent of the total solids held in solution by it consisting of this salt, while the waters of Bear river and City creek are characterized by carbonate of lime."‖ Strictly speaking, in the last case as commonly when carbonate of lime is in solution, the lime is in the form of the bicarbonate. During the process of aeration caused by the beating of the waves against the shore carbon dioxide is given off and the lime, reduced to calcium carbonate, is deposited.

The oolitic sands may be ascribed to the action of plants which have the power of withdrawing carbon dioxide from soluble calcium bicarbonate, which would precipitate the insoluble carbonate.§ Deposits of calcareous tufa and oolite are particularly

* U. S. Geological Survey, Monograph 2. Lake Bonneville, p. 254.
† Ibid. p. 256.
‡ Ibid. p. 169.
‖ Ibid. p. 207.
§ Russell. Lakes of North America, p. 76.

abundant near the mouths of streams which convey carbonate of lime to the lake and possibly the lime carbonate is wholly withdrawn from the inflowing water before it has an opportunity to mingle with the more remote waters of the lake.

Basins which are in some degree connected with the ocean may next be considered. The Bessarabian coast of the Black sea furnishes an example of salt deposits in bays slightly connected with the ocean and fed from the landward side by rivers. From the Danube to the Dnieper the rivers before emptying into the ocean expand into lakes which are separated from the sea by natural dams. Under ordinary circumstances the water flows into the sea through an opening in the dam, while during storms the water of the sea enters the lakes. Three of these lakes become partially dry every summer and deposit salt which in places amounts to a layer a foot thick*. This salt is used for commercial purposes. The calcium sulphate of the river water and of the sea water which is driven in during storms must also be deposited, but the quantity being small readily escapes notice.

Many writers on gypsum and salt have called attention to the fact that the Mediterranean Sea furnishes conditions which if but slightly modified would result in deposits of these substances.† Although it receives the waters of many rivers, some of them of considerable size, evaporation takes place faster than inflow and if no water entered through the Strait of Gibralter, or if the supply entering were considerably reduced, much of the mineral matter held in solution would be deposited. A steady current pours in from the ocean, however, and the density nec-

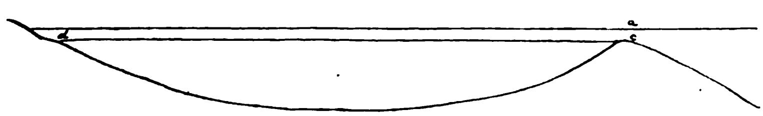


Fig. 15.

essary for precipitation is not reached. The bottom of the sea rises sharply near the Strait of Gibraltar cutting off communication between the lower part of the sea and the ocean, but permitting a free interchange of water in the upper level. The depth at the strait is less than 200 fathoms while the average depth of

* Bischof, Vol. I, p. 392.
† Geol. Surv of Mich., Vol. V, 1881-93, part II, pp. 1-13.
University Geol. Surv. of Kansas, Vol. V, Gypsum. Introduction.

the Mediterranean is 1,000 fathoms. The accompanying diagram roughly illustrates existing conditions.

The amount of salt in the water of the Atlantic is 3.6 per cent, while in the Mediterranean it is 3.9 per cent. The specific gravity of the water of the Atlantic off the strait of Gibraltar is 1.026, while at the west end of the Mediterranean, near the surface, it is 1.028, increasing in the east end to 1.03. At a depth of 300 fathoms the density is considerably greater than at the surface. A current of water flows in constantly at the surface of the strait (Fig. 15, a). This water is concentrated by evaporation and sinks. The bottom below the line c d has been previously filled by this dense water and the water is being constantly condensed, sinks and flows out at c as a lower current into the ocean. The outlet at the strait is so free that the condensation does not reach the point which results in the deposition of lime, gypsum or salt.

It is quite conceivable that the opening could be so restricted that the outflow would be greatly diminished and the density of 1.05 to 1.13 which is necessary for the deposition of limestone be reached. If this were maintained for a long time and the inflow were enough to prevent further concentration a thick layer of limestone without gypsum and salt would be formed. If the opening were still further restricted gypsum would be precipitated and at length salt. In this case, however, the calcium carbonate in the inflowing sea water would be precipitated with the gypsum unless converted into gypsum or a more soluble salt by reaction with other salts or isolated during deposition as is the case today in Great Salt Lake. The amount of the calcium carbonate (one-tenth as much as the gypsum) if present would be easily recognized. If instead of a small opening the inland sea were shut off from the ocean by a low barrier, over which the sea water passed only in time of great storms, the deposits might be more varied. The water would be diluted at times so that precipitation of the more soluble salts would cease and after a period of evaporation, if the amount of calcium carbonate in the newly added water were considerable, there would be a deposit of limestone succeeded by gypsum. A series of limestone and gypsum beds occurs in the northern peninsula of Michigan near St. Ignace.

In applying "enclosed sea" conditions like those now prevailing about Great Salt Lake, to the Iowa gypsum, two questions arise. Was there a supply of gypsum in the rocks of the region subject to the solvent action of stream water sufficient to yield the existing deposit? If this question may be answered in the affirmative, do the deposits formed in enclosed seas structurally and chemically resemble those of Webster county? The Coal Measure shales and sandstones with here and there a limited area of Saint Louis limestone formed the land surface when the gypsum was deposited. There is a considerable amount of gypsum in all of these strata which appears frequently in large selenite crystals. Rivers flowing over this surface would carry a large percentage of gypsum in solution, provided the gypsum now contained in these strata was present at that time. It is hardly probable that the gypsum of the Coal Measure shales was formed at the time of their deposition, for the presence of great numbers of ferns indicate fresh water. A more probable origin lies in the action of water on pyrites, giving rise to ferrous sulphate, which in turn changed part of the lime carbonate of the shales into gypsum. This may have taken place before the great gypsum deposit was made and if so the gypsum dissolved out of the Coal Measure shales may have been sufficient to form it. The same waters which carried the gypsum would, however, carry much lime carbonate and mud, and it is difficult to conceive of fifteen feet of pure gypsum forming in an enclosed basin fed by streams. It is true that at the top in one or two localities thin layers of limestone, sandstone or shale occur with thin layers of gypsum, but the presence of fifteen feet of gypsum with only one per cent of sand and clay practically precludes the possibility of its origin in an inland basin fed by land streams. Turning to the "Mediterranean hypothesis," there are two apparent difficulties. In the series of deposits due to deposition on account of evaporation in such a basin, limestone would be the lowest member. If the amount of calcium carbonate in the waters tributary to the basin was small limestone might not appear beneath the gypsum as a distinct formation, but mixed with the finer impurities would still be present as a notable calcareous element in a clay or shale. The Iowa gypsum overlies a fire clay,

the analysis of which shows but a very limited amount of lime. Moreover, the lime carbonate in the inflowing water after the density necessary for the deposition of gypsum had been reached in the basin, would, it would seem, be deposited with the gypsum. The phenomena observed about Great Salt Lake perhaps relieve us of these difficulties. As already stated, the water of the lake is almost free from calcium carbonate, while deposits of calcareous tufa and oolite have been and still are forming along the shores where water action is violent. This localizing of the calcium carbonate, if it were complete, would render possible deposits of pure gypsum like that of Iowa, in which no calcium carbonate appears. Unfortunately calcium carbonate due to precipitation from solution appears widely distributed in the marl of the old Bonneville bed, as well as along the shore.* Still the fact that calcium carbonate deposits were favored at the shores by the aeration associated with wave action is particularly significant. Even more significant is the fact that near the streams which contribute to the lake the greatest amount of lime carbonate, the calcareous oolite already mentioned, accumulates as a shore deposit in considerable quantities. If in this or some similar way the lime carbonate was localized the Mediterranean hypothesis would appear satisfactory. It is possible also, holding to this hypothesis, to assume that chemical reactions took place between the salts in solution, which resulted in the elimination of this lime carbonate, either by converting it into gypsum or into a salt which was more soluble than gypsum, thus keeping it in solution till after the gypsum was deposited. It is well known that reactions between the various salts contained in sea water may cause divergence from the series which results from evaporation alone. According to Usiglio sea water deposits limestone abundantly when the density reaches 1.0506 and again at 1.1304. The last deposit he ascribes to the decomposition of sodium carbonate and gypsum with the formation of sodium sulphate and calcium carbonate.† Ochsenius holds that sudden and well marked deposits of gypsum may be caused by the addition of sodium or calcium chloride.

The same line of reasoning which is used to explain great de-

* U. S. Geol Surv , Monograph 1. Lake Bonneville, p. 190.
† Hubbard, Geol. Surv. of Mich., Vol. V, part II, pp. 1-3

posits of gypsum may be applied to many limestones. Calcium carbonate in sea water is one-tenth as abundant as calcium sulphate and for every twenty feet of gypsum two feet of limestone must be precipitated, unless the calcium carbonate is converted into some other substance. Since the density required to precipitate limestone is far below that required for deposition of gypsum it is highly probable that in many shallow seas but slightly connected with the abyssmal ocean limestone was continuously and abundantly deposited. Such deposits must be more widespread than gypsum for the same reasons that gypsum deposits must be more abundant than salt. While laying stress on this point the fact probably remains that most of the limestone of the earth is of organic origin.

While conditions like those now existing in the Mediterranean sea may in the main be regarded as giving rise to gypsum deposits, this sea presents one peculiarity which could not have characterized many of the regions where gypsum occurs. Structural conditions indicate that most of the gypsum deposits were formed in arms of a shallow epi-continental sea. The Mediterranean sea with its average depth of 1,000 fathoms is truly abyssmal.

Although there may be some doubt as to the exact manner in which the calcium carbonate is removed from the brine during concentration, the fact that it is removed in some one or more of the ways suggested, or by some process not yet brought to light, may be assumed. This removes the only serious difficulty in conceiving of extensive and very pure deposits of gypsum forming in basins only slightly yet continuously through long periods connected with the ocean. The Mediterranean hypothesis, with the modifications pointed out, may be accepted as accounting for the Iowa gypsum as well as similar deposits in various periods of geological history. It must be admitted, however, that chemical investigations in regard to the reactions between salts in solution during the process of brine concentration must be undertaken before the problem can be regarded as fully solved.

Pleistocene System.

Throughout the county the surface material has been derived from sources other than the decay of the underlying rocks. The soil-forming agents to which the county owes its fertility were the ancient glaciers and their deposits which consist of clay, bowlders and pebbles lawlessly mixed and spread evenly over great stretches of country are called drift. The geological system to which these deposits belong is the Pleistocene. Positive differences in the nature of the drift have led most students who are engaged in its study to the conclusion that these deposits were not all made at one time and by a single invasion but rather by a series of ice sheets. The last ice invasion was comparatively recent, so recent that the drift deposits that it left behind are but slightly oxidized and are almost unmodified by subsequent erosion. This latest drift is called the Wisconsin. Under topography attention was called to the slight amount of erosion over the surface of Webster county as contrasted with counties in the southern part of the state which are covered with the older Kansan drift.

Webster county lies within the boundaries of the Wisconsin drift as determined by geological observations through this portion of the state. The drift was not always deposited with uniform surface or thickness. This natural unevenness of the drift aids the drainage, which is still very imperfect. Streams have been able to modify the surface but slightly and then only in their immediate vicinity. At many points in the county the slope is away from the stream. A striking instance of this may be seen on the river at Fairview, two miles above Fort Dodge.

In addition to the topographic features, which aid only in determining the age of surface drift, its physical and chemical characteristics throw much light on the age of the deposit. Fortunately there are many localities in Webster county which give complete vertical drift sections. Some of these are as follows:

Section in the pit of the Fort Dodge Brick and Tile Works:

		FEET.
4.	Drift, light yellow, not very compact, slightly jointed, unleached, with many lime pebbles	4
3.	Drift, in most places sharply defined from above, but at times thin layers are worked in with it, gray in color, with many limestone pebbles, some are oxidized but show no ferretto, effervesces with acid less than 4	13
2.	Drift, not sharply defined from 3, yellow, deeper in color than 4, jointed, very compact, oxidized, especially along joints, effervesces almost as vigorously as 4	10
1.	Coal Measures	50

On the south side of the same pit another interesting section is given. This is well down in the valley of the Des Moines, about thirty feet above the alluvium.

		FEET.	INCHES.
5.	Drift, giving place to silt in the lower part of the section	6	
4.	Sand, yellow, cross-bedded, gradually growing harder from top to bottom, gradually shading into 3		10
3.	Sandstone, yellow, soft above, very firm beneath, cross-bedded, in turn shading into 2	1	6
2.	Conglomerate composed of northern bowlders, granite, etc., cemented by sand and iron all highly oxidized. The largest bowlders 16 inches in diameter, some of the bowlders perhaps faceted though oxidation renders surface features indistinct	1	
1.	Shale, Coal Measure	6	

The sandstone in this section lies in a small hollow, running north and south, in the Coal Measures. The relationship between the different members of this section is shown in the accompanying sketch (Fig. 17). The gravels and bowlders in No. 2 are badly rusted, and many of them are decayed, in which case they show oxidation throughout. Beneath the sandstone they are firmly cemented to form the conglomerate, which gradually shades into the sandstone above. To the right, as shown in the sketch, the sandstone shades gradually into sand, which for a few feet over-

FIG. 10. Portion of clay pit of Fort Dodge Brick and Tile Company, showing the upper yellow drift sharply separated from the lower blue-gray drift.

lies the cemented bowlders and pebbles and then gives place to silt. As the distance from the sandstone layer increases, the cementing in the conglomerate becomes weaker until the conglomerate appears simply as a very old gravel deposit. Gravels fully as old as those shown in this section occur on a level about ten feet higher, at the foot of Central avenue, above Heath's Oat Meal Mill.

AFTONIAN GRAVELS.

The presence of the sandstone layer in the second section given above, taken in the pit of the Fort Dodge Brick and Tile Company, is remarkable. The stone, although appearing only as a single layer, is as substantial as the Dakota sandstone of the Cretaceous. If it were seen away from its surroundings it would certainly be regarded as much older than the Pleistocene. The following considerations, however, lead to the belief that it is

merely a very old and very firmly cemented glacial sand. This sandstone lies just above and unconformable with the Coal Measures, and if it is not Pleistocene, it is to be associated with the gypsum. In the pit of the Fort Dodge Clay Works just across the river shales of the gypsum series are exposed in direct contact with the Coal Measures. At that point no such conglomerate or sandstone appears. While the surface features of the bowlders are so indistinct on account of oxidation that none of them can be said to be striated, some of them appear to have been planed on one or more sides. The overlying sand, which no one would hesitate to call Pleistocene, shades so gradually into the sandstone that it is impossible to draw any line between them. This sandstone and the gravel, viewed as Pleistocene deposits, are doubtless very old and may perhaps best be classed with the Aftonian gravels found elsewhere in the state.

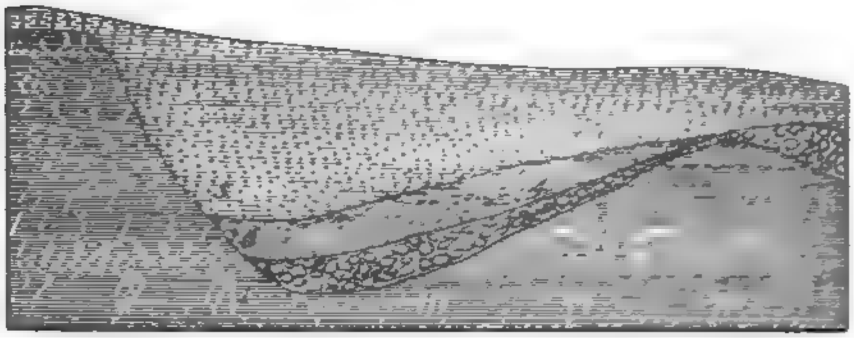


FIG. 17. Old gravel in the pit of the Fort Dodge Brick and Tile Works. 1. Coal Measure shale. 2. Glacial conglomerate and uncemented bowlders and sand. 3. Sandstone. Cross-bedded shading up into. 4. Uncemented sand. 5. Wisconsin drift.

WISCONSIN DRIFT.

Drift section in the pit of the Fort Dodge Clay Works.

	FEET.	INCHES
5. Drift yellow, unleached, with few bowlders, those which are present being fresh, many of them of limestone and striated, many limestone pebbles	4	
4. Drift, yellow, but slightly darker than 5, imperfectly separated from 5, except in color like 5	6	

		Feet.	Inches.
3.	Red sandy shales, calcareous, in places showing thin layers of sandstone containing no fossils, unconformable with the drift, and with the underlying Coal Measures	4	
2.	Dark gumbo layer, conforming to the uneven surface of the underlying Coal Measures		6
1.	Coal Measure shales	30	

Slide two miles below Fort Dodge, on the river opposite Blandon's Mill.

		Feet.
6.	Drift, light yellow, not compact, unleached, many limestone pebbles	35
5.	Drift, gray, except in color like 6	20
4.	Drift, bright yellow, except in color like the drift above	10
3.	Drift, gray, with same characteristics as 5.	30
2.	Gypsum (exposed)	10
1.	Shale, Coal Measures	60

In the drift of this section careful searching failed to reveal any difference in leaching from top to bottom.

Section at Bradshaw and Moeller's clay pit in West Fort Dodge.

		Feet.
5.	Silt like material, fine-grained and free from lime and pebbles	5
4.	Gravel, fresh, water worn	1
3.	Drift, yellow, unleached, no distinct oxidized zone	15
2.	Aqueo-glacial sands and clay, finely stratified, an occasional bowlder near the top, sand getting coarser and more abundant toward the bottom till all is sand	30
1.	Shale, Coal Measures (exposed)	10

This clay pit is near the valley of the Des Moines on a tributary ravine. The upper silt which is free from lime (5 in the section just given) probably represents the silt of the second bench and similar deposits may be found at a number of points along the river.

Section at Miller's quarry (formerly Baehring's) near the stone bridge over Soldier creek in Fort Dodge.

		FEET.
8.	Soil	2
7.	Gravel, clean, fresh, water worn, cross bedded with much lime tone	10
6.	Drift, not compact, yellow, unleached, somewhat jointed	15
5.	Soil, very dark, unleached, containing many foreign pebbles and wood fragments	15
4.	Sand, uncemented, varying in color from gray to white containing lumps of coal and large pieces of wood	8
3.	Sandstone, single heavy layer	2
2.	Limestone, Saint Louis	25
1.	Sandstone, in creek bed	1

Drift sections at Kohl's brewery, in Gypsum Hollow and on the hillside near the Fort Dodge cemetery have already been given. An interesting series of drift exposures may be seen on the Lehigh branch of the Mason City and Fort Dodge railroad, where the road descends to cross the river, two miles above Lehigh. The cuttings are eight or more in number and most of them are forty or fifty feet deep. In a number the upper drift is yellow and overlies a blue-gray stratum from which it is rather sharply distinguished. Yet very close to sections showing both yellow and blue drift are others fully as deep in which only yellow is found.

Other sections might be recorded but they would add nothing to the data already given. After studying many of the sections found in the county and considering the data given by well drillers, the following general statements seem to be warranted. In thickness the drift varies from fifty to one hundred and thirty feet. The upper drift, always yellow, frequently differs in color from the lower. The latter in many sections, however, is exactly like the upper, though generally more compact. When drift of two colors is found in a section the separating line is not always sharp, though it is frequently very distinct. The drift nowhere shows much difference in leaching from top to bottom. At no point was a highly oxidized or ferretto zone observed. At two localities in the valley of the Des Moines river soil beds were found covered by drift. The light colored pebbles characteristic of the Wisconsin drift were found throughout all drift sections regardless of depth. Nowhere was loess found, the only

substance resembling it being the silt occurring at the Bradshaw brickyard.

Old Soils and Gravels.—Excepting the very old gravels in the pit of the Fort Dodge Brick and Tile Works and at the foot of Central avenue, Fort Dodge, and the soil beds with the thin drift layer beneath them, the drift of the county may be regarded as Wisconsin. The absence everywhere of loess and of the dark brown oxidized zone so characteristic of the Kansan surface, the absence also of leaching in any part of the drift, render doubtful the correlation of any considerable portion of the drift with the Kansan. The soil and drift found at Baehring's quarry beneath the Wisconsin drift (described under Stratigraphy) may be thought to represent the Kansan and the long interval which elapsed before the Wisconsin. The extraordinary thickness (fifteen feet), however, shows that it is a soil formation out of the usual order. The abundance of wood in large pieces with fragments of coal, especially the cross-bedded sand shown in No. 4 in the Baehring quarry section, render likely the supposition that the deposit was delta-like in origin.

Variation of Color in the Wisconsin.—The presence of light-colored limestone pebbles and of limestone blocks, many of them striated, so generally prevalent, are positive Wisconsin characteristics. The frequent variation in color, however, is not common in the Wisconsin drift. This phenomenon is explained by supposing that the Wisconsin within itself varies somewhat in age. It is certain that across the Wisconsin drift in Iowa a series of moraines may be traced which are rightly regarded as moraines of recession. One of these is conspicuous south of Webster county, at Pilot Mound. Two others cross northern Webster county. Between the deposition of these moraines there may have been a decided retreat of the ice, leaving the surface bare for a considerable period. A subsequent advance would result in a drift deposit above the first, from which probably the first would be differentiated. In Illinois Leverett* finds an early Wisconsin drift outside of a late Wisconsin series of moraines. In the Wisconsin he has noticed variations in color similar to those found in Webster county. They differ, however, in being

* U. S. Geol. Surv., Monograph, 38. The Illinois Glacial Lobe, p. 191.

more persistent. It would be impossible to found a belief in an earlier and later Wisconsin simply on the color variations in the drift of Webster county.

Coon Mound Esker.—In connection with the topography of the county a hill in Lost Grove township, section 9, locally known as Coon Mound, was described. It belongs to the esker type of glacial deposit. The country around it is extremely level, the nearest series of morainic hills lying six miles to the south. Its height is fifty feet, and the dimensions of its base are 500 by 300 feet, the longer axis extending north and south. Pebbles and water worn sand enter largely into its composition.

Morainic Belts in Webster County.—The hills and ridges of northern Webster county, described in connection with the topography of the county, were shown to be constructional and independent of erosion, which is the ordinary agent producing an uneven surface. They may be grouped in two series, each having a trend from west-northwest to east southeast. The northern range extends from section 3, Jackson township, eastward to a point a mile beyond the river, and has an average width of two miles. It includes many comparatively level tracts. The hills are but thirty or forty feet high, and their slopes are gradual,

FIG. 12. Morainic knobs in Wisconsin drift, northern Webster county

offering no hindrance to agriculture. Bass lake formerly filled a hollow between these morainic hills. Associated with these hills are kames, which are capable of yielding great quantities of gravel. One is found in Deer Creek township, section 10, Sw. ¼, and another in Badger township, center of section 8.

The town of Clare is situated on the western end of the second morainic belt, which extends eastward from Clare across Deer Creek township, its northern limit passing through the center of sections 15, 16, 17 and 18, and thence extending southeast to section 25. Its average width is two miles. Forming a part of this moraine, in Deer Creek township, section 26, Sw. ¼, is the highest hill in the county. The southern extension of this moraine is found in Douglas township, sections 2, 3, 4, 11, 12 and 13. By the roadside in the middle of section 10, outwash gravels may be seen. A small morainic area east of the river, including the kame in Badger township, section 19, Sw. ¼, may be associated with this range.

A third morainic tract, smaller than the two just described, is found east of Tara and south of the Illinois Central track. This tract is referred to by Upham,* who suggested that it might be a part of the Gary moraine, and that it might be found to connect at the south with the moraine which is so well developed at Pilot Mound. Careful study of the region to the south, however, does not support this supposition. This morainic tract extends across parts of sections 27 and 28, Douglas township. In the middle of section 28 there is a kame yielding gravel.

Pre-Wisconsin Valley of the Des Moines.—If the topographic evidence alone is considered, the valley of the Des Moines must be regarded as very young. Its width is not great and its sides, although for the most part composed of soft material, are exceedingly steep. The country adjacent to the river is but slightly dissected and tributary streams within the county, great and small, are few. The stream seems to be reworking a pre-Wisconsin, perhaps pre-Kansan, valley. The evidence is revealed in deep cuttings in both banks, the best instances being the pits of the Fort Dodge Clay Works and the Fort Dodge Brick and Tile Works, which are on opposite sides of the river. At these points

* Ann. Rept. State Geologist Minnesota, p. 305, 1880.

the Wisconsin drift is seen to come far down the slopes, to the very edge of the flood plain, while the indurated rock, here Coal Measure shale, has a contour quite independent of drift, which on the steep banks is unassorted and cannot be regarded as hill-side wash. The position of the shale is practically horizontal and the old valley was independent of synclinal folding. Mining in the gypsum along Two Mile creek shows that the courses of minor streams are determined by pre-Wisconsin drainage. Near the creek the gypsum, though covered by a very heavy layer of drift is found to be badly cut up by the erosion of a stream which followed the course of the present creek. Wisconsin drift apparently nearly filled the valley, but a depression sufficient to determine the course of the subsequent stream remained. The inability of the Wisconsin drift to materially alter drainage lines within the county raises a question in regard to the thickness of this drift. If all of the eighty or one hundred feet of drift within the county is Wisconsin, it would seem sufficient to wholly obscure a small valley like that of Two Mile creek. Yet the nature of the drift precludes the possibility of ascribing any of it except certain gravels insignificant in extent, to any agent except the Wisconsin ice. The old gravels already described, which occur in a depression a little above the present flood plain of the Des Moines river, indicate a hollow here before the Kansan drift covered the region. If the valley has been continuously occupied by a stream as large as the present Des Moines, the extent of the cutting in the Coal Measures seems small. Allowance of course must be made for the fact that the drift from two ice sheets filled the valley and had to be removed before the stream could attack the indurated rock. Taking this fact into account, it still is probable that the interglacial stream was smaller than the one now occupying the valley.

Terraces on the Des Moines.—Remnants of an extensive gravel terrace high up on the banks of the Des Moines river are found in the vicinity of Fort Dodge. A portion of it constitutes the fair ground and the gravels are well exposed on Soldier creek at Miller's (formerly Baehring's) quarry, near the stone bridge in Fort Dodge. It appears also back of the city hospital and on the bank of the river in west Fort Dodge, Cooper township, section 30, Ne.

¼ of Se. ¼. Such gravel terraces along streams traversing or bordering the Wisconsin drift are not uncommon. During the retreat of the glacier vast quantities of water were discharged into the streams till their energy was sufficient to carry heavy loads of detritus in the form of sand and gravel for many miles. The feature of this gravel terrace that is unusual is its elevation above present water level.

The facts considered in the preceding paragraph suggest an explanation. If the valley at the retreat of the Wisconsin ice was nearly filled with drift while yet some depression remained, the glacial stream issuing from the ice during its retreat would naturally follow this old channel. Gravels would be deposited abundantly, the greater part of which would be carried away as the stream cut down through the soft underlying drift, leaving only here and there fragments of the deposit in the form of a terrace. The gravel terrace is now 150 feet above water level. The river has cut only a few feet into the indurated rocks since the Wisconsin ice, and the conclusion follows that the valley was filled with drift to a depth of nearly 150 feet. This is probable, for the drift on the level often reaches this depth.

In the lower valley, where a gravel terrace might be looked for, a terrace of silt, brown in color, fine-grained, free from sand and pebbles, and containing very many shells of the land snail Mesodon, is found. Dr. Beyer speaks of a similar terrace in his report on Boone county.* It is twenty feet above the alluvial bottom land and is made up of the same material that is found in the lowest part of the valley. The silt terrace along the Des Moines is shown in figure 27 and its relation to prehistoric remains found above Lehigh is discussed in a separate paragraph.

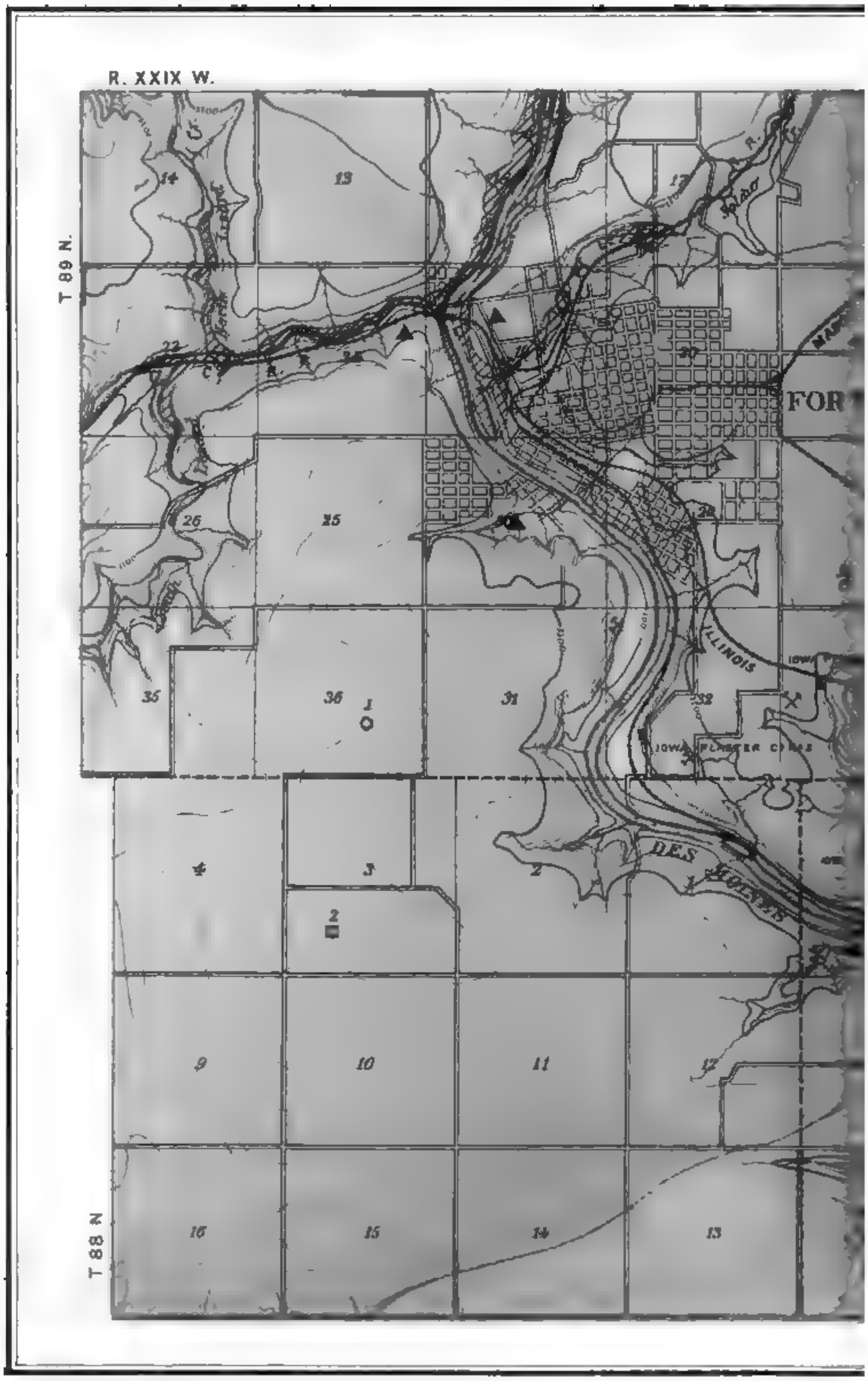
ECONOMIC PRODUCTS.

Gypsum.

COMPOSITION AND CHARACTERISTICS OF GYPSUM.

Gypsum is sulphate of calcium with water of crystallization. It is represented by the chemical formula $CaSO_4+2H_2O$, the water of crystallization forming 20.93 per cent of the whole. Gypsum

* Ann. Rept. Iowa Geol. Surv., Vol. V, p. 182.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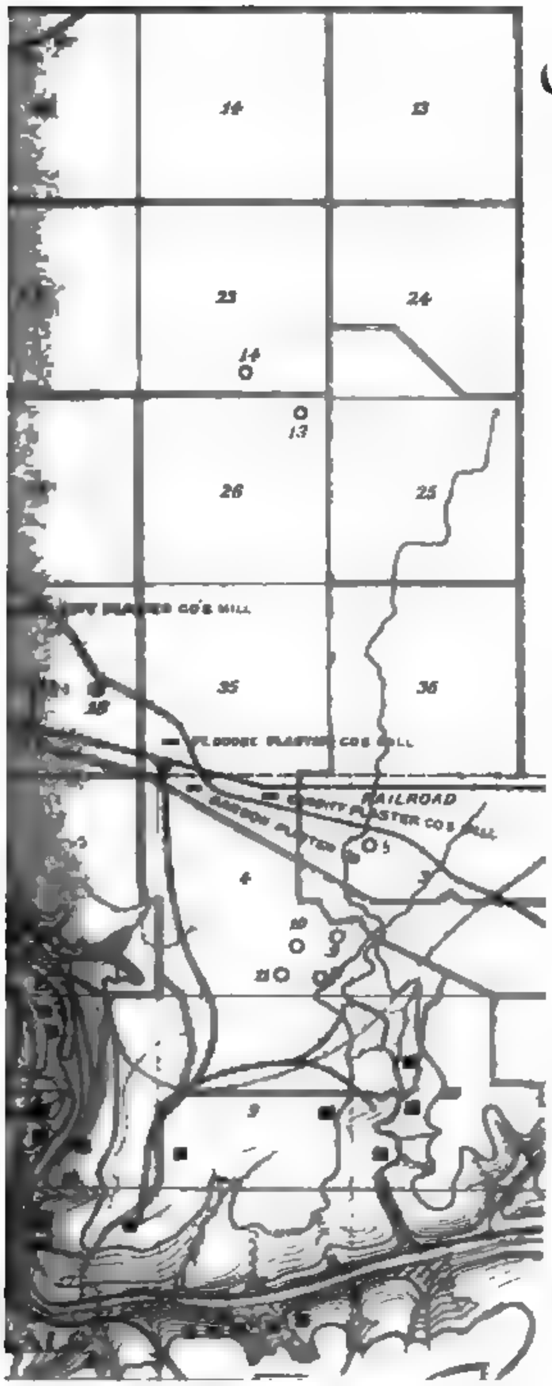


A GEOLOGICAL MAP OF THE IOWA GYPSUM REGION IMMEDIATELY ABOUT FORT DODGE

BY

CHARLES R. KEYES

AND

FRANK A. WILDER

TOPOGRAPHY BY

E. H. LONSDALE AND F. HESS.

1902.

EXPLANATION

PERMIAN
GYPSUM

DES MOINES

SAINT LOUIS

GYPSUM MILL

GYPSUM MINE

BORINGS WHICH
ENTER GYPSUM

COAL MINES

CLAY WORKS

occurs most abundantly in sedimentary rocks with sandstone, limestone and rock salt. In volcanic regions it is often found in limited quantities filling cavities in lava. Its presence there is ascribed to the sulphur exhalations always present in volcanoes. Gypsum crystals are common also in the clays and shales of various geological ages in Iowa, particularly in those of the Coal Measures. Anhydrite is a mineral having the same chemical formula as gypsum, but lacking the water of crystallization. On exposure to the air it may take on this water and become gypsum. In its crystalline form gypsum is called selenite. By mineralogists selenite is placed in the monoclinic system. The common form is the vertical prism. Cleavage is nearly perfect parallel to the face 010, and this gives rise to the common belief that the mineral is mica. Twin crystals are common, the twinning taking place along the orthopinacoid. Gypsum according to its natural structure is considered under the heads of, 1. crystalline gypsum or selenite; 2. fibrous gypsum, when fibers are very long, called satin spar; 3. granular gypsum, when white called alabaster; 4. gypsum powder or gypsum earth.

Gypsum may be wholly colorless and transparent, as in selenite; or may be white, red, green, blue, gray or brown. It is quite soft, its hardness ranging in terms of the Mohr scale, from 1.5 to 2. Its specific gravity with that of products made from it, contrasted with limestone and lime mortar, is shown in the following table:

Limestone	2.46 to 2.84
Quicklime	2.30 to 3.18
Lime mortar	1.64 to 1.86
Gypsum	2.30 to 2.40
Calcined gypsum	1.81
Portland cement	2.72 to 3.05

Gypsum is somewhat soluble in water, the solubility varying with the temperature, as shown in the following table of Marignac* which has been verified by Grimsley*:

* Annales de Chimie Paris, 5th Ed., Vol. I, pp. 274-281. Quoted by Chatard, 7th Ann. U. S. Geol. Surv., and by Grimsley in the Univ. Geol. Surv. of Kansas, Vol. V, p. 86.

TEMPERATURE.	ONE PART GYPSUM DISSOLVES IN—	ONE PART ANHYDROUS SULPHATE LIME DISSOLVES IN—
At 32° F=0° C........	415 parts of water..........	525 parts of water.
At 64.5° F=18° C......	386 " "	488 " "
At 75.2° F=24° C......	378 " "	479 " "
At 89.6° F=32° C......	371 " "	470 " "
At 100.4° F=38° C.....	368 " "	466 " "
At 105.8° F=41° C.....	370 " "	468 " "
At 127.4° F=53° C.....	375 " "	474 " "
At 161.6° F=72° C.....	391 " "	495 " "
At 186.8° F=85° C.....	417 " "	528 " "
At 212° F=100° C......	452 " "	572 " "

NATURE OF THE WEBSTER COUNTY GYPSUM.

The mode of occurrence of the Webster county gypsum has been more minutely set forth in this report under the heading stratigraphy. A concise restatement, however, is in place at this point. It lies directly under the glacial drift which varies in thickness from one to one hundred feet. Natural exposures occur along the Des Moines river which crosses the gypsum area and along many of its tributaries. The gypsum forms a practically horizontal bed, varying in thickness from ten to twenty-five feet. It is of the finely fibrous variety, nearly free from impurities and not interspersed with layers of foreign material. Crystals rarely occur in the layers of fibrous gypsum, though they are common in the Coal Measure shales of the county.

EXTENT AND AVAILABILITY OF WEBSTER COUNTY GYPSUM.

It may be safely affirmed that there are from sixty to seventy square miles of territory underlain by gypsum. Future prospecting will enlarge this estimate rather than diminish it. At least forty square miles may be considered available for economic purposes. A limited portion of the total area will prove unavailable on account of the thinness of the deposit. Prospecting has also demonstrated that at points within the gypsum area the gypsum has been removed by preglacial erosion. For this reason careful prospecting should precede the choosing of a site for mill purposes. As is shown by the map, the gypsum area is cut in two by the Des Moines river, and large quantities of the mineral have been removed by the erosion of this stream and its tributaries. Away from the river

Upper surface of gypsum bed.

Topography of gypsum area.

the topography of the gypsum area is that of a very level prairie. In the early days of the gypsum plaster industry the natural exposures in the bluffs along the river and along Two Mile creek were regarded as most available. At present, however, the gypsum on the prairie away from the river is conveniently mined by means of shafts. The gypsum area is crossed by four railroads; the Chicago, Rock Island and Pacific, the Minneapolis and Saint Louis, the Illinois Central and the Mason City and Fort Dodge. Shipping facilities, therefore, are excellent.

PERMANENCE OF THE GYPSUM SUPPLY.

The great thickness of the gypsum in Webster county and its purity, together with its extent make the supply practically inexhaustible. The Iowa Plaster Company estimates that, since beginning operations in 1872 it has removed the gypsum from only fifteen acres. A conservative opinion as to the total amount of gypsum removed up to date (summer, 1900) places it at twenty-five acres. If the gypsum area is regarded as only fifty square miles in extent, certainly a moderate estimate, there remains twelve hundred and eighty times as much gypsum as has been removed since the beginning of the plaster industry. The average thickness of gypsum suitable for plaster is ten feet and the yield per acre of such gypsum is at least 30,000 tons.

DISTRIBUTION OF GYPSUM AND MARKETS FOR GYPSUM PRODUCTS IN THE UNITED STATES.

As an initial step in an analysis of the future of the Iowa gypsum plaster industry, it is necessary to review the development of the industry in the country at large, in order to determine the likelihood of more vigorous competition in the future and from what quarters it may be expected.

In the first place deposits of gypsum are restricted to very limited and widely scattered areas. Since the finished product is heavy, cost of shipment will always be a large factor in determining the portion of country that can be reached by any producing area, and will give each area an advantage over the others in a certain amount of territory. Gypsum near the Rocky Mountains and farther west will never compete with the Iowa mineral

and deposits in this region need not here be considered. In the region east of the Rockies gypsum is found at the following localities:

New York.—Gypsum is found at a number of points from Buffalo as far east as Madison county. Deposits of considerable thickness lie at moderate depths beneath the city of Buffalo but are unavailable on account of the amount of water present which prevents mining. The largest quarries in the state are at Union Springs where sixty tons a day are quarried.

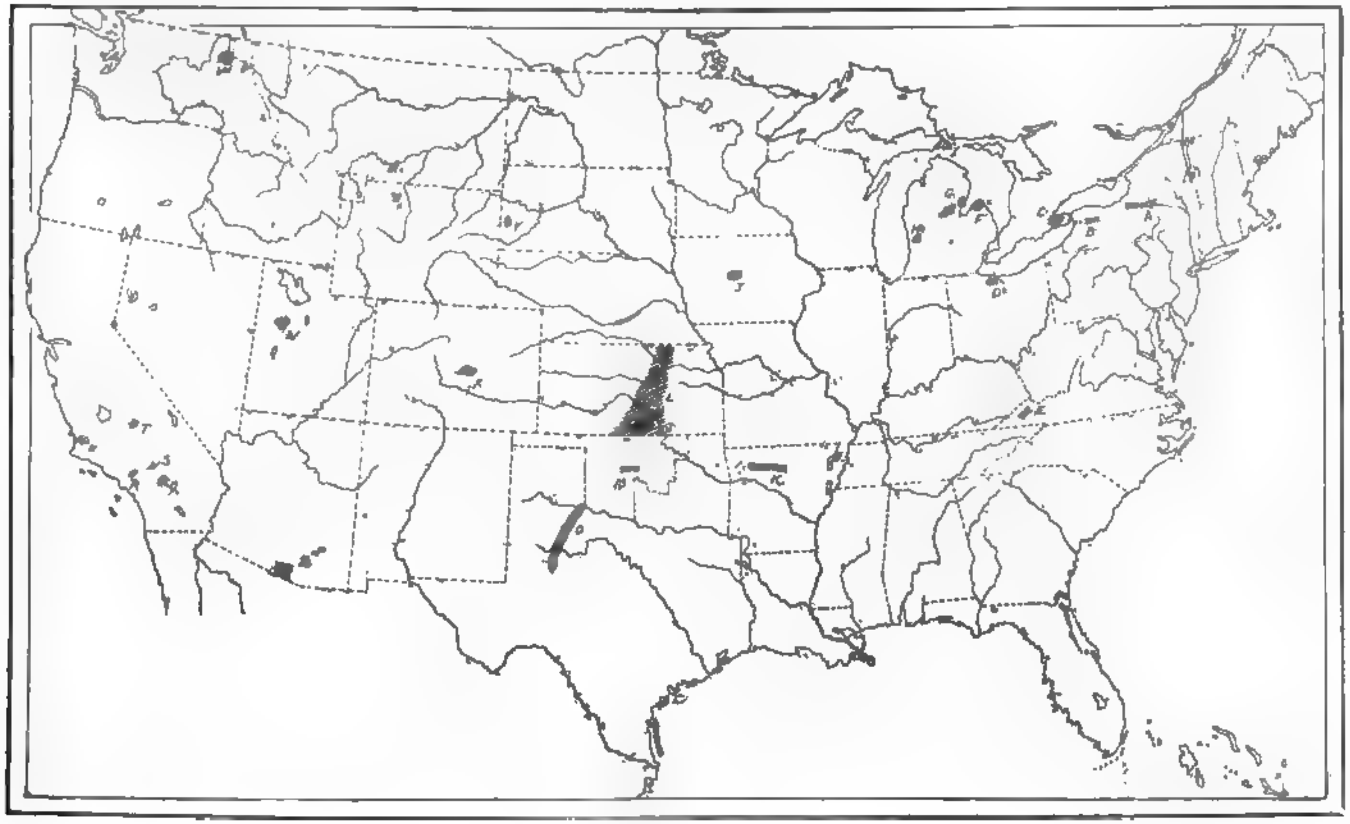
Gypsum in layers of considerable thickness occurs near Syracuse and much of it is reported as suitable for plaster of Paris and wall plaster.

Ohio.—Deposits of gypsum of economic importance occur at a single point in Ohio, in Ottawa county, ten miles west of Sandusky. The area is small and is nearly all under the control of mills already established. A large portion of the product is converted into crayon.

Michigan.—In this state gypsum has been most extensively developed in Kent county near Grand Rapids. Here five mills each with a daily capacity of seventy-five tons are in successful operation. The mineral is obtained by stripping and mining, as its depth varies from two to seventy feet. These mills are not able to avail themselves of cheap lake freight rates since the Grand river is navigable for only part of the forty miles which lie between Grand Rapids and the lake.

The Michigan gypsum series forms a ring nearly ten miles wide about Lansing as a center. It varies in depth and thickness and not until the eastern side of the state is reached are the deposits again economically significant. At Alabaster in Iosco county on Lake Huron, the gypsum outcrops directly on the lake and is utilized by a large plaster mill which is located there. From the same point the uncalcined rock is shipped to Chicago where it is converted into wall plaster. Across the bay, in Huron county, gypsum is also found but the extent of the deposits here is not known.

In the vicinity of St. Ignace gypsum exists in considerable quantities in close proximity to the lake and though the deposits promise well they are at present wholly undeveloped.



Map showing distribution of gypsum in the United States; areas at least partly developed are dotted, while undeveloped areas are indicated by diagonal lines.

Virginia.—Stretching across Smyth county and entering Washington county in southwestern Virginia is a gypsum area of large proportions. The amount exposed on the surface covering a tract twenty miles long and two miles wide, is not remarkably great but a known thickness of 592 feet for the deposit makes the quantity of mineral per acre very large; estimated by Boyde* at 666,000 tons. The region is traversed by the north fork of Holstein creek and by the Norwalk and Western railroad.

Kansas.—Eleven operating mills in Kansas place that state in the front rank of gypsum producers. The raw material is found at very many points through a tract averaging eighty miles in width and stretching from the northern to the southern boundary of the state. Mills are most numerous near Blue Rapids in the northern part of the state; in southern Dickinson county, in the center and near Medicine Lodge, in the extreme south. The gypsum deposits are of two varieties: (1) gypsum rock not unlike the Iowa mineral, (2) earth and mud plaster which consists of fine gypsum crystals loose, through which a certain amount of clay is disseminated. Six mills use gypsum rock and five gypsum earth. The gypsum earth requires no mining or quarrying for, lying on the surface in deposits from six to ten feet deep, it can be excavated with scrapers. The clayey impurities do not seem to be an especially undesirable element.

Texas.—The gypsum deposits of Texas are said to be the most extensive in the United States. In thickness they vary from one to twenty feet and extend from the union of the North Fork and Red river on the north-central boundary to the town of Sweetwater in the center of the state.† The Texas and Pacific railroad reaches the deposits at Stillwater and the Fort Worth and Denver near Quanah.

South Dakota.—An abundance of gypsum in the Black Hills has resulted in the erection of one or two small mills in the vicinity of Hot Springs. The deposits are excellent but the absence of a convenient market and limited fuel will always greatly restrict the industry.

Canada.—Immense deposits of gypsum in Canada conveniently located for ocean shipment have had a definite effect on the gyp-

* Resources of Southwest Virginia, 1881.
† Geol. Surv. of Texas, 2d Ann. Rept., 1890.

sum industry of America. These are the deposits in Nova Scotia which are quarried and sent to New York for development. The extent of this industry is shown in the tables below.

*Production of Gypsum in the United States, in tons of 2,000 pounds.**

STATES.	1898.	1899.	1900.
California	3,875	3,663	*e* 3,500
Colorado	1,570	1,600	4,000
Indian Territory and Oklahoma	15,229	20,750	16,975
Iowa	38,338	51,958	92,201
Kansas	49,720	82,016	*e* 90,000
Michigan	93,181	144,776	150,000
Montana	400	304	325
New York	46,477	39,390	42,874
Ohio	*e* 23,000	25,000	25,000
Oregon	150	500	450
South Dakota	3,750	600	750
Texas	24,417	34,214	42,000
Utah	*e* 3,000	1,700	2,247
Virginia	8,125	12,773	10,885
Wyoming	3,633	2,817	2,995

e estimated.

The average price per ton in 1899, for crude gypsum was $1.14; for land plaster $2.01; for plaster of Paris $3.91.† The average value of wall plaster for 1900 may be estimated at $4.75.

*Gypsum imported into the United States in metric tons.**

YEAR.	GROUND OR CALCINED.		UNGROUND.		Value of manufactured plaster of Paris.
	Quantity.	Value per ton.	Quantity.	Value per ton.	
1896	3,348	$ 6.58	183,165	$ 1.06	$ 11,722
1897	2,707	6.29	165,812	1.08	16,715
1898	3,021	6.12	168,723	1.09	40,970
1899	3,317	5.80	199,724	1.10	58,073
1900	3,159	6.07	213,239	1.08	66,473

Most of the unground gypsum was shipped from Nova Scotia to mills in New York.

* From Mineral Industry, R. P. Rothwell, 1900.
† 21st Ann. Rep. U. S. Geol. Surv., 1899-1900.

*Production of gypsum in the principal countries.**

YEAR.	CANADA.	FRANCE.	UNITED KINGDOM.	UNITED STATES.
1894	202,877	....	155,905	273,553
1895	205,187	2,456,150	180,738	237,399
1896	187,818	2,051,124	196,404	201,305
1897	217,392	2,004,339	184,287	272,493
1898	198,909	2,115,261	199,174	285,644
1899	221,862	1,978,963	215,974	382,891

The production in Germany cannot be stated exactly, no statistics being given for Prussia where the industry is best developed, but it probably falls but little short of that of France.

On account of limited shipping facilities the mills of South Dakota cannot send their goods to a field where they compete with the Iowa product. Freight rates also favor the Iowa over the Michigan and Kansas mills throughout a considerable territory. There is no gypsum in Iowa outside of Webster county, and competition from other points within the state is impossible. With the growth of population the demand for gypsum plaster will increase. The dark days in the history of the gypsum industry were at the time of the introduction of hard plaster. Those times have long since passed and every year gives a fuller recognition to the worth of gypsum plasters. The accompanying report on the German gypsum industry suggests a number of ways in which gypsum products may be multiplied.

Those who hold land underlain with gypsum will meet with disappointment if for this reason they value it at an extravagant figure. The great production of gypsum per acre limits the demand for gypsum land. Not before some hundreds of years have elapsed will the amount of available gypsum land become limited. Nearness to railroads gives certain tracts an advantage of course, which will appear in an increased valuation.

HISTORY OF THE GYPSUM PLASTER INDUSTRY IN WEBSTER COUNTY.

The first gypsum mill in Webster county was erected in 1872 at the head of Two Mile creek, better known as Gypsum Hollow, close to the Illinois Central track. It has recently been remodeled and is now known as the Central mill of the Iowa Plaster Asso-

* From Mineral Industry, R. P. Rothwell, 1900.

ciation. The founders of the gypsum plaster industry in this state were Captain George Ringland and Messrs. Webb Vincent and S. Meservey.

At this time gypsum was used only for making finishing plasters. Experiments were undertaken to prove the worth of calcined gypsum in making hard wall plaster. In 1878 small quantities of material prepared for this purpose were put upon the market. It was not taken up readily by builders, but in time its worth was made clear. Had the use of gypsum been confined to the making of finishing plasters the industry could never have attained its present proportions. In 1882 the lower mill in "Gypsum Hollow" was erected, and this was followed in 1885 by the Blandon mill. The interests represented by these three mills were later consolidated, and are now known as the Iowa Plaster Association. Shortly after the erection of the Blandon mill, the Duncomb mill was built at the mouth of Two Mile creek. Thus three mills stand today on "Gypsum Hollow," through which Two Mile creek flows. In 1895 the Cardiff mill, representing Fort Dodge capital, began operations. This was the first of the mills built on the prairie. On account of the thickness of the drift stripping was impossible, and mining by means of a vertical shaft was begun. The success of this mill encouraged the erection of other mills on the prairie, and in 1899 the Crawford mill was completed, and in the spring of 1900 the Mineral City mill made its first shipments. Another mill is at present (August 1900) under consideration. Most of the stock for this mill has been subscribed in Waterloo and Fort Dodge. The location selected is in Pleasant Valley township, Nw. 1/4 of section 4. Drillings at that point show forty feet of soil and red shale, and seventeen to twenty-two feet of gypsum. The seven mills in operation at present have a total capacity of 600 tons of stucco per day of ten hours. The location of all of the mills and mines is shown on the small geological map of the region immediately about Fort Dodge.

NATURE OF GYPSUM PLASTER.

Gypsum plaster is gypsum that has been finely ground and then calcined. This latter process consists in uniformly heating the

gypsum to a temperature of 120°-130° centegrade (250°-270° Fahrenheit.) During the process the gypsum loses 14 per cent of its water of crystallization. Chemical analysis shows that the gypsum ($Ca\ SO_4 + 2H_2O$) by calcining is changed to the hydrate ($(Ca\ SO_4)_2\ H_2O$). A temperature as low as 80° centigrade has been found sufficient if calcining is continued for a very long time.

The property on which the value of gypsum plaster depends is its tendency to "set," or form a hard, firm mass when water is added to it. It is of interest for both theoretical and practical reasons to know the causes of the setting of stucco. The following statement is a condensation of the more elaborate explanation of Grimsley* whose experiments confirm and enlarge on the previous work of Marignac and Chatelier.

When water is added to gypsum plaster, a certain amount of the gypsum is taken into solution. When a solution is saturated, it requires but little to start the process of crystallization from solution. The presence of crystal fragments is an excellent incentive to crystallization from such a solution. These fragments are furnished by the coarser particles of stucco. About these as nuclei the crystals of gypsum rapidly grow, each molecule of the hydrate taking to itself three molecules of water, either in the process of solution or of crystallization or of both, in accordance with the following formula:

$$(Ca\ SO_4)_2\ H_2O + 3\ H_2O = 2\ (Ca\ SO_4 + 2\ H_2O.)$$

The growth of gypsum crystals in this manner, from the saturated solution of the stucco or hydrate, constitutes the "set" of plaster.

It is well known that the setting power of calcined plaster is lost or injured if the ground gypsum is either over calcined or under calcined. Calcining accomplishes two things. It breaks up into fine particles the ground gypsum, and drives off part of the water of crystalliation. If the gypsum is under calcined, therefore, the hydrate is not formed, and if it is over calcined the particles are so comminuted that they no longer furnish the crystalline nuclei necessary to start the setting. The finer the gypsum is ground, the more readily it is taken into solution, and the more readily plaster made therefrom sets. Coarser fragments

* Univ. Geol. Surv. of Kansas. Vol. V, pp. 94-96.

are still abundant enough to furnish the necessary nuclei. Fine grinding does not destroy the setting power of gypsum plaster, as over calcining does.

NATURE OF RETARDER.

Nearly all of the calcined gypsum made in Iowa is used for hard wall plaster and only a limited amount is sold for finishing. At the mills the calcined gypsum is mixed with retarder and hair for the convenience of the user. Seven pounds of retarder and one and one-half pounds of hair are added to each ton of calcined gypsum. Stucco sets naturally in from six to fifteen minutes. In spreading on walls and in manipulating in other ways, it cannot be handled so rapidly and consequently it was found necessary to introduce something into the plaster that would check the setting. Anything that will interfere with the rapid growth of the crystals will bring about the desired result. Blood was used as a retarder by the ancient Romans. Glue water was formerly mixed with the plaster by the workman as he used it. At present the trade demands a plaster through which the retarder is already uniformly mixed. The amount of retarder necessary is small. Very many combinations to be used as retarders for gypsum plasters have been invented. In the Fort Dodge mills, a retarder made at Webster City, Iowa, is commonly used. In many of the patent retarders, glue, glycerine, sawdust, slaked lime and fiber are the chief ingredients. In regard to the effect of retarder on the strength of plaster opinions differ. A good retarder should simply hinder the growth of crystals and contain nothing which by decay will cause disintegration in the mass in which it is contained. Retarders having these properties probably do not weaken the plaster. Less retarder is used in summer than in winter. After retarder is added to calcined gypsum it keeps a much shorter time. When retarder is mixed in calcined gypsum the plaster deteriorates somewhat after two months in summer and six months in winter.

PRODUCTS OF AMERICAN GYPSUM MILLS.

Hard Wall Plasters.—Most of the calcined gypsum of America, as has already been said, is used in plastering interior walls. For

this purpose it is mixed in proportions given in the preceding paragraph with hair and retarder. In this form it leaves the mills packed in sacks or barrels, and is given to the building trade. The builder mixes it with sand and water just before he is ready to apply it as a covering for an interior wall. The higher the percentage of sand that can be mixed with a gypsum plaster, the better from the standpoint of economy. The gypsum which the building trade supplied by the Iowa mills demands, and with which it is furnished, is a gypsum plaster which will make an enduring wall when mixed with twice or three times its own bulk of sand. Gypsum plaster has important advantages over lime plaster with which it is in direct and active competition. It is more decidedly a nonconductor of heat. It sets and dries out more rapidly than lime plaster, and interiors where it is used as wall covering may be pushed to completion much more rapidly. Ceilings and walls in which gypsum plaster was used have been thoroughly water soaked without injury. As a fireproofing material it is rapidly assuming importance. For this purpose it may be used alone, or be mixed with asbestos. When mixed with ten per cent of lime and allowed to set its hardness is greatly increased and it sustains a high polish.

Calcined Plaster and Plaster of Paris.—This is simply ground and calcined gypsum to which no retarder or hair is added. Large quantities of this plaster are used by the glass factories of the country. So great is the amount used by these that its ability to supply economically a limited number of them with gypsum plaster would alone be sufficient to warrant the development of a gypsum area. The gypsum plaster is used to make the level beds on which the glass is poured. Having been used once it may be reground and so reused a limited number of times, but its setting power is soon exhausted and it must be put aside for fresh material. When ground very fine and calcined gypsum constitutes plaster of Paris, which is used for a variety of purposes in many of the arts. Calcined plaster has, among other uses, been mixed with Paris green and sold as a poison for insects attacking potatoes and other vegetables. While not a poison itself, it dilutes the Paris green so that it does not injure the plants. It prevents the poison from being washed off by rains and greatly adds to its

effectiveness. Calcined plaster is used also as a filler for some of the finer grades of paper. For this purpose gypsum is usually ground, calcined, mixed with water, allowed to set and then reground.

Limited quantities of calcined plaster are used in making Keene's cement and various imitations of marble, according to methods about equivalent to those described in the accompanying report on the German gypsum industry.

New uses for gypsum plaster are being developed in connection with electrical fittings. Ordinary plaster of Paris is porous, readily absorbs water and having done so becomes a conductor of electricity. This water absorbing property may be overcome and the material hardened at the same time. It then becomes a useful material in electrical fittings, when the parts are neither under high tension nor exposed to high temperatures or sudden changes of temperature. In these cases the expensive putty of litharge and glycerine must be used. The following hardeners for gypsum plaster to be used in electrical fittings are recommended by a recent writer in the Scientific American.

1. Add 2 to 4 per cent of powdered marshmallow root and knead to dough with 40 per cent water. The mass resembles fat clay, and may be cut, filed and drilled; 8 per cent of marshmallow root makes it still harder. Dextrin, gum arabic and glue may be used.

2. Six parts gypsum, one part fresh slaked lime; the articles made therefrom to be soaked in concentrated magnesium sulphate solution.

Water absorbing power may be removed by saturating in a solution of ozokerite or wax in oil of turpentine or varnish.

Uncalcined plasters are used as fertilizers and in the manufacture of paint. Limited quantities are mixed with the shale and limestone used in making Portland cement.

GYPSUM AS A FERTILIZER.

Land plaster, which is the name commonly applied to ground but uncalcined gypsum, has long been recognized as a fertilizer of considerable and in some cases of remarkable merit. Allusion is made to it in Roman literature of classic times. In the eigh-

teenth century its successful use in Germany as a top dressing for clover was recorded. Benjamin Franklin scattered land plaster in a field of clover, so as to form the sentence, "This has been plastered with gypsum," and the sentence is said to have been legible on account of the great height and color of the clover thus fertilized. Mr. C. W. Johnson in 1841 wrote a prize essay for the Royal Agricultural Society of England, entitled, "An Account of the Application of Gypsum as a Manure to the Artificial Grasses." He quotes from the letter of a Hampshire farmer as follows:*

"The soil of my farm is of a clayey nature and would be very stiff but for the number of stones there are in it. I have sown gypsum six or seven years and never on clover or saintfoin without satisfactory proof of its efficacy, having usually grown one-half ton more of hay per acre by its use. But the effect in 1838 was wonderful. I put on a bag ($2\frac{1}{2}$ cwt.) per acre on a two year old piece of saintfoin on the first of May with the plants very forward, just leaving the ground and coming to stalk; the gypsum had so increased the growth of the grass by the ninth of the same month that when crossing the land with a friend we observed the difference from one of the fields to the other; and at harvest time the extra produce of hay was quite one ton per acre. * * * I can even see the effect where three years ago the gypsum was spread. I always leave a strip or two in every field to prove the effect. There is one thing more I wish to observe, that I never put in gypsum before the last week in April or first in May, and choose if possible a moist morning. I have not found much good effect from its application on either chalk or cold clay soils." Boyd in his "Resources of Southwest Virginia" records experiments of a like nature, by which lands practically worthless are made very productive by a moderate application of gypsum plaster.

Boussingault in 1841 analyzed clover grown on land fertilized with gypsum and found a great increase in the mineral constituents, notably in lime, magnesia and potash.

Many experiments, undertaken scientifically and carried out by practical men, show that for certain soils and crops gypsum is a fertilizer of great value. There have been many theories to

* Univ. Geol. Surv. of Kansas, Vol. V, p. 126.

account for its beneficial action. It has been thought that the gypsum holds the carbonate of ammonia which rain water takes from the air. The fact that gypsum absorbs moisture readily and gives it off during times of drouth has by others been regarded as its useful property in agriculture. Sir Humphrey Davy thought that gypsum yielded directly lime and sulphur for plant food. At present, the value of gypsum as a fertilizer is thought to depend on properties wholly different from those just suggested. It has been demonstrated that gypsum decomposes the double silicates that are abundant in many soils, especially in clay, and sets free a soluble potash sulphate. This potash is of great value to plants, especially to the Leguminosæ which include clover, beans, etc.

Land plaster is essentially a clover manure, and generally gives more satisfactory results with this crop than any other. It is most suitably applied during moist weather, in the autumn or in the spring, while the crop is young. Two hundred pounds to the acre is the amount generally used. The native grasses are rapidly disappearing in Iowa, and the acreage of clover annually increases, and in the same ratio the importance of land plaster as a fertilizer for Iowa soils increases.

While gypsum has but little importance as a solvent for atmospheric ammonia, it is of great value if scattered about decaying manure, or sprinkled freely through the stables. Under these conditions it holds the ammonia that would otherwise be dissipated and when scattered on the soil with the manure yields it as food for plant growth.

Land plaster as put upon the market varies greatly in purity. Tests made by the Wisconsin Experiment Station show that the amount of pure gypsum contained in a number of samples varied from seventy-six to ninety-seven per cent, while one sample contained no gypsum whatever; the impurities were largely water and carbonate of lime, and certain insoluble substances which were of no value as fertilizers. The following tables of analyses were taken from Bulletin No. 14, University of Wisconsin, Agricultural Experiment Station.

In order to protect the farmers against imposition of this kind and to learn more about the quality of the different brands of

plaster sold in the state, the Station offered to examine free of charge all samples of land plaster sent beforè May 1st. In response to this offer the following samples were received and analyzed, with the results given below.

STATION NUMBER.

373. Sent by T. C. Decker, Beloit. This plaster was purchased in Milwaukee, and is probably a Michigan plaster.
374. Sent by E. P. Richardson, Ableman, Fort Dodge plaster.
375. Sent by S. E. Gernon, Waukesha, Michigan plaster.
377. Sent by S. C Fish, Reedsburg, Fort Dodge plaster.
378. Sent by H. J. Sutherland, Madison, Fort Dodge plaster.
380. Sent by Wm. N. North, La Crosse, Fort Dodge plaster.
382. Sent by R. B. Kellogg, Green Bay, Sandusky, Ohio, plaster.
383. Sent by S. C. Fish, Reedsburg, brand unknown.
384. Sent by Hiram Smith, Sheboygan Falls, Fort Dodge plaster.
385. Sent by Charles V. Guy, River Falls, Fort Dodge plaster.
386. Sent by Charles V. Guy, River Falls, brand unknown.
387. Sent by N. E. Becker, Random Lake, brand unknown.
388. Sent by Wm. Toole, Baraboo, brand unknown.
391. Sent by A. F. Noyes, Beaver Dam, Fort Dodge plaster.

The price for which these plasters were sold varied from $6.10 per ton to $10.50 per ton, much of the difference being due to cost of transportation.

STATION NUMBER.	INSOLUBLE IN ACID. PER CENT.	PURE PLASTER. PER CENT.
373	1.74	90.4
374	....	95.3
375	1.78	87.72
377	2.17	89.72
378	2.08	95.64
380	2.46	94.75
382	.31	93.61
383	1.50	93.15
384	1.29	93.24
385	2.37	95.31
386	1.09	93.85
387	2.08	87.81
388	2.21	94.32
391	2.12	95.98

"All of these plasters are of good quality, some of them being of exceptional purity. The difference in their quality may be largely attributed to the amount of moisture which they contain. Plaster kept in damp places will often retain several per cent of hygroscopic water, which adds just so much to its weight. Before making large purchases of plaster, one should be sure that it has been kept kept in a dry place, and that it is ground quite fine. A coarse plaster does not dissolve readily and is not as prompt in its action. As a rule, light colored plasters are purer than dark colored ones."

GYPSUM AS A BASIS FOR PORTLAND CEMENT, WITH SULPHURIC ACID AS A BY-PRODUCT.

Keyes, in his report on the Iowa gypsum in 1893, suggested that profit might be derived from gypsum if it were used in the manufacture of Portland cement and sulphuric acid. He pointed out that the shales which must be used with the gypsum to produce cement and acid are abundant in the immediate vicinity of the gypsum. A patent numbered 342,785, issued on June 1, 1886, to Uriah Cummings of Buffalo, New York, outlines the process. The greater part of the description given in this paper is reproduced below:

"Hydraulic or Portland cement is usually manufactured by mixing together clay and carbonate of lime in such proportions that after calcination the resulting compound will contain about sixty-two parts of lime, twenty-eight parts of silicic acid and ten parts of alumina by weight. During the process of calcination the carbonic acid contained in the carbonate of lime is expelled, and the silicic acid combines with the base and forms therewith silicates of lime and alumina, which are afterward reduced to powder, and known as hydraulic or "Portland" cement. The carbonic acid which is expelled during the process of calcination has no commercial value, and is allowed to escape into the air.

The object of this invention is to reduce the cost of the cement by its production as a by-product in the manufacture of sulphuric acid; and the invention consists to that end in manufacturing sulphuric acid from clay or silicic acid and sulphate of lime, as will be hereinafter fully set forth, and pointed out in the claims.

In practicing my invention I mix together gypsum or sulphate of lime and clay in the proportion of about twelve hundred and sixty-six pounds of gypsum to four hundred pounds of clay. I prefer to pulverize the gypsum and dry the clay and pulverize the same, then intimately mix the pulverized gypsum and clay and add a small quantity of water, and mold the mixture into blocks substantially in the manner practiced in making Portland cement from carbonate of lime and clay by the well known dry process. I then subject this mixture to calcination in a suitable kiln. At the high degree of heat which is maintained during the process of calcination the silicic acid contained in the clay expels the sulphuric acid contained in the sulphate of lime and combines with the lime and alumina and produces there-

with silicates of lime and alumina, which, upon being reduced to powder, are in every particular a hydraulic or Portland cement. The sulphuric acid is expelled during this process of calcination either in the form of vapor, or it is decomposed and forms sulphurous acid and oxygen; or perhaps the escaping gas is a mixture of vaporized sulphuric acid, sulphurous acid and oxygen, according to the degree of heat which is maintained during the process of calcination, and which may vary somewhat at different times, owing to differences in the quantity or quality of fuel employed, strength of draft, etc. The gases escaping during the process of calcination are cooled in suitable chambers or passages lined with lead, in which the sulphuric acid is condensed and collected. The sulphurous acid, if any, is converted into sulphuric acid in the ordinary manner by means of steam and nitric acid. The sulphuric acid so obtained is then concentrated or further treated in any usual manner practiced in the manufacture of sulphuric acid. The mixture of gypsum and clay above specified produces about seven hundred and eleven pounds of hydraulic or Portland cement and five hundred and eighty pounds of sulphuric acid from every sixteen hundred and sixty pounds of the mixture, the balance being moisture, which is expelled. The cost of the sulphate of lime is about the same as that of carbonate of lime and the cost of manufacturing hydraulic or Portland cement by this improved method is about the same as that of the old method in which carbonate of lime is employed; but the sulphuric acid which is obtained in my improved method is valuable, and the value which it represents materially reduces the cost of the cement.

In practicing this invention any suitable kiln in which the process of calcination can be carried out may be employed, and any ordinary apparatus may be used for recovering the sulphuric acid.

The condensing and converting chambers are connected with the top of the kiln by a suitable flue, and the waste gases are discharged from the condensing or converting chambers by a stack or chimney or a suitable fan which maintains a proper draft through the kiln and chambers.

The proportions herein specified are found to be well calculated to produce the desired results; but they may be varied in accordance with the nature of the gypsum rock and clay employed within certain limits without changing the general results. If the proportion of clay used be too great, the cement will be of an inferior quality but the sulphuric acid contained in the sulphate of lime will be driven off and recovered. If an excess of gypsum be used, the lime contained therein is in excess of the true combining proportions with the silicic acid, and the sulphuric acid will not be driven off and the resulting cement will be inferior in quality by reason of the presence of sulphate of lime, although a small percentage of the latter may be present without exerting any specially deleterious influence.

It is well known that silica or silicic acid contained in the clay is the active ingredient in the production of the cement and it is therefore obvious that silica in a finely pulverized condition may be substituted for the clay, if desired.

I am aware that it has been proposed to manufacture cement from carbonate of lime and clay with the addition of a small quantity of sulphate of lime or some other súlphate, for the purpose of rendering the mixture

eighteen parts water. The mixture is burned at a low heat for six hours.

"Parian cement is made from gypsum hardened by means of borax. One part of borax is dissolved in nine parts of water, and the gypsum is treated with the solution; sometimes one part of cream of tartar is added to the solution with good results.

"The hardened cement plaster is made at one mill in Kansas, the Best Brothers' mill, at Medicine Lodge. The gypsum blocks are burned in the kiln, and then treated with a secret solution and reburned. This plaster withstands a crushing force of 3,000 pounds and a tensile strain of 698 pounds after seven days in air. It is claimed to be equal to the imported Keene's cement, and superior to Portland cement for plastering purposes or for laying dry walks. This cement is not used much in Kansas, but has been received with favor in the eastern cities."

GYPSUM AS A BASIS FOR PAINT

For some years the Iowa Paint Manufacturing Company has operated a mill at Fort Dodge and has built up a large and profitable demand for its paints. They have been well received by the trade and have stood successfully the many severe tests to which they have been put. A striking instance of their durability is seen in the Fort Dodge water tower. This structure is of iron and steel and is unusually exposed to the action of the elements. The water rises and falls in the large tank that surmounts it, and the paint that covers it is subject to constant changes in temperature. Three years ago the tower and tank were covered with paint made at the Fort Dodge mill and the paint has not as yet been injured by this constant exposure.

Gypsum is used as a basis for the paint. It is crushed in machinery similar to that used in the plaster mills and ground by passing through two impact oscillators made by Raymond Brothers, Chicago. These oscillators consist of covered cylinders in which revolve metal blades that are attached to iron collars; the oscillators are run at a very high rate of speed and the crushed gypsum is quickly reduced to powder by the blades. A fan forces a current of air through the oscillators and when the gypsum reaches the desired fineness, which is regulated by the

strength of the air current, it is lifted by the air to the upper oscillator where it goes through a similar process. The gypsum is ground much finer than when used for plaster. Ninety-nine and nine-tenths of it will pass through a No. 74 mesh, 99.7 per cent will pass through a No. 100 mesh, and 82.3 per cent will pass through a No. 200 mesh. The machines in use will grind to this fineness one and one-half tons per day, while they would grind to the fineness required for wall plaster five or six tons. Proper pigments are mixed with the ground gypsum and a very pleasing variety of colors result. All of these pigments are at present imported into the state. The gypsum used in the manufacture of paint is not calcined.

MECHANICAL PROCESSES IN MAKING HARD WALL PLASTERS, PLASTER OF PARIS, ETC.

During the earlier days of the plaster industry about Fort Dodge, the gypsum was obtained by first stripping off the drift which at the points where the gypsum was quarried varied in thickness from one to twenty feet. The gypsum was quarried by the simplest methods of drilling and blasting. The definite lamination of the gypsum greatly aided in this process. The large blocks that were blasted from the face of the ledge were broken by sledges into convenient size and hauled to the mills in wagons. Today, however, most of the gypsum is mined either by drifting into the deposit at natural exposures along streams or by shafts. The system of mining is still in evolution but in general the room and pillar method common in coal mines is followed. Hand drills are used for the most part, and after the drill has been set it is possible to bore a hole in the gypsum three feet long and two inches in diameter, in twenty minutes; ten minutes are required to set the drill. Coarse powder is used in blasting. For an ordinary blast the two-inch hole is filled with powder six inches, and tamped with clay or gypsum powder. On the average two tons of rock are removed at each blast. In most of the mines the miners are paid by the ton, forty-five cents being allowed for each ton when loaded on the cars. The miner furnishes the powder. At the mine of the Fort Dodge Plaster Company pneumatic drills have been used and pronounced satisfac-

Fig. 19. Interior of Crawford mine.

tory, while at the Cardiff mine an electric mining machine has given good results. The great thickness of the gypsum aids materially in mining. By leaving two or three feet above a good roof is obtained. In most of the mines the passages are nine feet high. At the Mineral City mine passages from fourteen to twenty feet wide are excavated and ten foot pillars are left. Water has not proved troublesome, although pumping more or

less constantly is necessary in the mines on the prairie. Where the gypsum is reached by shafts, it is carried underground on tramways to the shaft, which is always located near the mill. Some of the older mills are situated half a mile or more away from the mines that supply them. Tramways run from the mouth of the drift to the mill and the gypsum is hauled on small cars by mules or horses. After arriving at the mill it is stored for some time under sheds to permit the hygroscopic water to pass off. If the material is not thus dried, the power required for grinding is greatly increased and a considerable amount of fuel is wasted in driving off this water in the calcining kettles. It is considered desirable also to keep a supply on hand so that the mills may not be compelled to shut down on account of labor troubles or other difficulties in the mines. After drying in the sheds, the gypsum is again loaded on trams and run to a crusher which operates on the principle of an ordinary stone crusher. The gypsum being soft offers little resistance to the heavy metal jaws, and on passing through the machine is reduced to fragments, the largest ones an inch in diameter. It falls directly into a nipper, which resembles an immense old-fashioned coffee mill. It consists of a large iron funnel with flanges set vertically on the inner face. Within it revolves a shaft armed with similar sharp flanges. Between the two sets of flanges, the movable and non-movable, the gypsum is ground till it falls out of the bottom of the funnel in pieces not larger than peas. These small fragments are carried by the buckets of a belt elevator to an upper floor where they are fed down through a spout into burr mills. Three of these mills grind the mineral as fast as it can be calcined in the three kettles with which most of the plaster mills are equipped. On emerging from the burr mills, the gypsum is in the form of a fine powder, seventy per cent of which will pass a No. 74 mesh, sixty per cent a No. 100 mesh, and forty-four per cent a

No. 200 mesh. The average diameters of the largest particles passing these sieves are as follows:*

No. 74......................................0.229 millimeters = .00901 inches
No. 100......................................0.115 m l imeters = .00452 inches
No. 200......................................0.069 mil imeters = .00271 inches

The gypsum powder is again elevated and then pours steadily down on a broad belt which transmits it to a large bin above the calcining kettles. From this bin it flows through spouts into the kettles.

The calcining kettles in use at present in the Iowa plaster mills each hold eight or ten tons of plaster. Sheet steel three-eighths of an inch thick is used in their construction. They are cylindrical, eight or ten feet in diameter and eight feet high. The base of the kettle is built into a furnace in such a way that the bottom and lower part are exposed to the heat of the furnace. Two large flues pass through the lower part of the kettle from side to side, through which the heated gases and smoke are conducted before entering the chimney. A pipe leads from the upper part of each kettle through which the steam from the calcining gypsum passes. Some of the finest of the plaster is carried out of the kettles in these stacks and settling on the mill, the ground and trees, whitens the landscape. At the upper mill of the Iowa Plaster Association these pipes enter a large room on the upper floor which is free from draughts and much of this fine plaster here settles to the floor and is saved. The amount is considerable, about a ton a day. A heavy shaft to which blades and chains, which drag on the bottoms of the kettles, are attached,

* The following tests for fineness of calcined plaster were made by Prof. A. Marston in the summer of 1900, from material purchased in the market. The sieves used were calibrated by standard methods, and the terms, No. 74, No. 100 and No. 200 mesh, stand definitely for the diameters given in the text above.

KIND.	PER CENT PASSING MESH.		
	No. 74.	No. 100.	No. 200.
Gypsum from Stucco Mills, Ft. Dodge	68 3	60.0	44.0
Stucco from Ft. Dodge Plaster Co., Ft. Dodge, Iowa	71.9	65.2	49.3
Baker Stucco, Kansas	72 9	58.3	39.5
Kallolite Stucco, Cardiff Gypsum Plaster Co., Ft. Dodge, Iowa	69.1	63.8	50.2
Baker Plaster, Kansas	68 2	58.7	28.2
Mineral City Wall Plaster, Ft. Dodge, Iowa	72.1	65.4	49.1
Oklahoma Cem. Plaster Co., Okarche, Oklahoma Ter	77.8	70 2	51.3
Flint Wall Plaster, Iowa Plaster Association, Ft. Dodge, Iowa	72.4	64.2	48.1
Acme Wall Plaster, Acme, Texas	74.6	69 2	56.6
Kallolite Wall Plaster, Cardiff Gypsum Plaster Co., Ft. Dodge, Ia	70 8	65.5	53.5
Stonewall Plaster, Ft. Dodge Plaster Co., Ft. Dodge, Iowa	72.4	66.1	54 0
Duncomb Wall Plaster, Duncomb Stucco Co., Ft. Dodge, Iowa	63.8	57.8	43.6

Mill of the Fort Dodge Plaster Company.

constantly stirs the plaster. This shaft is vertical and rests in a box in the bottom of the kettle, and projects out through the metal cover. It is turned by a large horizontal crown wheel which is driven by a smaller vertical pinion. In filling the kettle a small stream of ground gypsum flows in for an hour or more. It is impossible to start the shaft which stirs the plaster after the kettle is filled.

FIG. 20. Mill of the Cardiff Plaster Company, Fort Dodge.

The temperature gradually rises in the kettles and the plaster begins to "boil." All over the kettle the plaster is thrown up into the air in jets by the escape of steam from below. This agitation of the plaster by the escaping steam greatly facilitates the stirring process. The temperature is determined from time to time by lowering a thermometer, by means of a long wooden handle. This must be left in the kettle for a long time if a true record of the temperature would be obtained, for the plaster forms a coating over the bulb, and as it is a good nonconductor of heat, the thermometer for some time fails to record the real temperature. Many of the calciners get along without the thermometer,

FIG. 22. Duncomb's Gypsum Plaster mill, Fort Dodge.

ings are more frequent. In the Chicago mills of the Western Plaster Works, and in a number of Michigan mills, lime disintegrators are used. The machine is said to work without choking or clogging, and to pulverize from sixty-five to seventy-five tons in ten hours. It is not certain, however, that they are an improvement over the burr mills.

The present method of calcining is wasteful of fuel. In similar industries greater progress has been made in fuel saving. The continuous kiln has been applied successfully to brick making and Portland cement burning. The saving of fuel accomplished by those kilns is considerable. Patents have been issued for continuous kilns suitable for stucco. Such patents are 573,140, U. S. Patent Office, issued to August Dauber, of Bocleum, Germany, 1896; No. 551,390, U. S. Patent Office, issued to F. M. Laude of New York, 1895; No. 519,063, issued to L. House of Montpelier, Indiana, 1894. The great difficulty in using a continuous kiln for calcining plaster is in securing a uniform temperature. The patents mentioned above are for kilns in which oil or gas is used for fuel. This may render them impractical in the Iowa field. A continuous kiln for calcining stucco, or a

FIG. 23. Blandon's Gypsum Plaster mill, Fort Dodge.

similar fuel saving device, is worthy of careful consideration and in this respect the German manufacturer is in advance of the American. Those who are interested in the subject will find a full description of continuous kilns now in use in Germany in the supplement accompanying this report which describes the gypsum industry of Europe.

The fine dust from the calcining kettles may easily be saved, and the amount will be found to be considerable. The heat from the cooling plaster is now wholly lost, and if a saving could be made here it would proportionately reduce the cost of calcining.

Coal.

The position and extent of the Webster county coal fields have been described, in connection with other Upper Carboniferous strata, under stratigraphy.

The coal in Webster county varies considerably in quality in the different basins, and often in different seams of the same basin. Some of it is excellent, while all is of fair quality. Since it constitutes the extreme northern point of Iowa's coal pro-

Holaday creek the upper coal has been mined for many years. The Holaday Creek Coal Company has operated on the creek, in Nw. 1/4 of section 10; J. L. Martin has a mine in this coal in Sw. 1/4 of section 10. From prairie level, in Sw. 1/4, section 16, Collins Brothers have developed the upper seam outside of the "big coal" from which they take a number of car loads of steam coal daily. At Kalo, in Sw. 1/4 of section 8 and Nw. 1/4, section 17, Otho township, the Craig Coal Company has mined the upper coal extensively. The Carlson mine is a little farther down the river and works the same seam, as do the McEwen mines a short distance up the river, on the east bank. Smaller mines in the upper bituminous seam near the river below Kalo are the Atherton and Woodbury, the Moore and Webster, the Mills and the Madison, all situated in a ravine on the west side of the river, one-fourth of a mile below the Kalo bridge. The Fuller mine is in a similar ravine one-eighth of a mile farther down the river. The Bennett, Jim Johnson and Everett mines are found on the river bank in the order named. The Eric Johnson mine is a mile below the bridge and works the Colburn vein, which is said to be two feet thick, and to lie twenty feet below the river.

The cannel coal about Kalo and Coalville will become more important as the output from the other seams diminishes. It is exposed along the river from the Minneapolis and Saint Louis railroad bridge in Se. 1/4 of section 6 to the Kalo wagon bridge in section 17. It extends back from the river on the right bank at least three-fourths of a mile. Prospecting has proven that the cannel coal basin includes an area of at least two square miles. In thickness the coal varies from two feet four inches to three feet. It has a good shale roof. On the left bank of the river the coal is mined on the Litchfield land, in Pleasant Valley township, Sw. 1/4 of section 5, where five men take out from ten to twelve tons a day. All of this is sold to the Duncomb plaster mill, which is a mile further up the river. The price paid for this coal is $1.65, delivered at the mill, the parties operating the mine paying a royalty of ten cents a ton. Directly across the river, in Otho township, section 8, Nw. 1/4, Irwin Brothers have a mine in the cannel coal, which here shows a thickness of two feet two inches. Their prospect holes in this vicinity show two feet of

coal ninety rods back from the river. The W. D. Johnson mine, also in the cannel coal, is a few rods above the Irwin mine. Collins Brothers mine the cannel coal on the left river bank, in Pleasant Valley township, section 17, Nw. ¼. The location of most of these mines is shown on the geological map of the gypsum region immediately about Fort Dodge.

In the Tara coal basin three companies are operating. In Elkhorn township, section 6, Ne. ¼, Martin and Timmons reach the coal with a sixty foot shaft. The seam here has a thickness of four feet six inches. They pay a royalty of fifteen cents for mine run. The room and pillar method is used in mining. This mine has been in operation for five years and the coal has been removed from an area of five acres. Piert and Colferd operate a mine on the same quarter section, and under about the same conditions as the mine just described. The coal is four feet thick, with gumbo or black jack for a roof and shale for floor. Drillings sixty rods south of this shaft also show four feet of coal. John Paul as a mine on the Patrick Scalley place, in section 33, Sw. ¼, which shows three feet and a half of coal reached by a forty foot shaft. The seam is practically horizontal throughout this district and differences in the depth of the shafts are due to surface inequalities.

At Limburg postoffice some coal has been mined. The Simpson and Gustafson shafts, both now closed, were operated for two years, about twenty tons being taken out of each mine per day. The Gustafson drift was operated on a small scale in the summer of 1900. Two men were taking out about a ton a day, the coal selling for $2.25 per ton.

A few tons are annually mined ten miles above Fort Dodge, from a seam which is commonly regarded as a part of the Colburn. The coal is of fair quality, though it slacks if exposed for a considerable time to the air.

ANALYSES OF WEBSTER COUNTY COAL.*

LOCALITIES.	Moisture.	Total combustibles.	Ash.	Volatile combustible matter.	Fixed carbon.	Coke—fixed carbon plus ash.	SULPHUR. In sulphides.	SULPHUR. In sulphates.	SULPHUR. Total.
Collins No. 6, Coalville, average	7.48	84.06	8.44	39.52	44.54	52.99	4.98	.26	5.24
Collins No. 4, Coalville, average	7.80	82.88	9.32	37.74	45.14	54.46	3.97	.12	4.09
Old Reese mine, Fort Dodge	9.92	48.77	41.31	29.69	22.08	63.39	......	....	.
Carlson mine, Kalo, average	10.10	76.53	13.36	32.83	43.69	57.06	1.68	.18	1.86
Craig Cannel mine, Kalo, "cannel" coal	5.87	78.26	15.87	39.04	39.22	55.09	6.87	.25	7.12
Craig slope, Kalo, bituminous	8.46	81.37	10.17	37.97	43.40	53.57	5.19	.10	5.29
Crooked Creek mine, Lehigh, top	7.74	78.94	13.32	34.47	44.47	57.79	4.83	.81	5.64
Same, middle of seam	8.52	82.65	8.83	38.64	44.01	52.84	3.71	.48	4.19
Same, bottom of seam	8.57	81.86	9.57	37.57	44.29	53.86	3.47	.18	3.65
Crooked Creek shaft, Lehigh	6.99	76.66	16.34	34.40	42.26	58.60	5.67	.37	6.04
Corey mine, Lehigh, average	7.77	81.27	11.00	38.05	43.21	54.21	7.02	.68	7.70

* Iowa Geol. Surv., Vol. II, p. 529, 1894.

	No. 1	No. 2	No. 3	No. 4	No. 5
Moisture..............	14.05	10.46	10.13	13.91	9.92
Volatile combustible...................	36.42	37.44	37.25	37.00	26.69
Fixed carbon.........................	41.19	36.93	36.08	41.83	22.08
Ash..	8.34	15.17	16.54	7.26	41.31
	100.00	100.00	100.00	100.00	100.00

CALCULATED ON DRIED COAL.

	1	2	3	4	5	
Volatile combustible	42.38	41.80	41.44	42.98	29.63	
Fixed carbon.......	47.94	41.26	40.15	48.59	24.51	
Ash	9.68	16.94	18.41	8.43	45.86	
	100.00	100.00	100.00	100.00	100.00	
Volatile combustible	50.47	47.90	47.38	50.91	36.6[illegible]	
Total combustible {	77.61	74.37	73 33	78.83	48.77	Of undried coal
	90.32	83.06	81.59	91.57	54.14	Of dried coal
Coke............. {	49.53	52.10	52.62	49.09	63.39	Of undried coal
	57.62	58 20	58.56	57.02	70.37	Of dried coal

COMPOSITION OF COKE.

Carbon................................	83.00	70.87	68.56	85.19	34.87
Ash	17.00	29.13	31.44	14 81	65.13
	100.00	100.00	100 00	100.00	100.00

No. 1. From Rees' mine, near Fort Dodge.
No. 2. "Lower Cannel Coal" from bank of Des Moines river, Sec. 17, Tp. 83 N.' R. 29 W.
No. 3. From Sec. 17, Tp. 88 N., R. 28 W.
No. 4. "Collins' mine," Sec. 17, Tp. 88 N., R. 28 W.
No. 5. "Cannel Coal" from Rees' mine, Fort Dodge.

An analysis of Tyson coal taken from the left bank of the river in the summer of 1900 gave the following results:

Moisture	12.70
Volatile matter	44.12
Fixed carbon	32.91
Ash	10.27
	100.00
Sulphur	5.33

Clay.

An abundance of suitable clay conveniently exposed along the Des Moines river furnishes material for a variety of clay goods. Brick and tile are made at Fort Dodge, Coalville and Lehigh. A pottery at Fort Dodge produces stoneware of excellent quality, and in considerable quantities. In addition to building brick, Webster county is a large producer of paving and sidewalk brick. Some of the plants are finely equipped with modern machinery and kilns. An excellent market exists on account of the scarcity of material in many of the counties north, east and west, and the price of building brick for the past two years has ranged from five to six dollars a thousand.

Fort Dodge Brickyards.—The Fort Dodge Clay Works is situated on the right bank of the Des Moines river, conveniently near the Illinois Central railroad with which it is connected by short side tracks. The pit extends into the bank, and the clays consist of drift, shales of the gypsum formation and Coal Measures. Sections of this pit have been given elsewhere. The drift is used as sparingly as possible and only when mixed with the other clays, for it carries so much lime that its excessive use would seriously injure the quality of the brick. The clay is loaded into cars in the pit, which are drawn to the mill by a steam windlass. A stiff mud end cut machine made by the American Clay Manufacturing Company is used for working the clay. From the mill the brick go directly into spacious driers. A large continuous kiln and four down draft kilns—two round and two square—give large burning capacity. The plant produces 45,000 brick per day, one-fourth of them of the paving variety. Recently this company has opened up a pit on the banks of the Lizard, near its mouth. The clay here consists of red and green shales which are associated with the gypsum. Saint Louis limestone appears on the banks below the pit.

The Fort Dodge Brick and Tile Works, a firm composed of J. H. Able, Wm. Fessel and F. Moeller, operate a large plant directly across the river from the Fort Dodge Clay Works. It is shown in the foreground of Fig. 25, while the pit and kilns of the Fort Dodge Clay Works appear in the distance. The clay

used is a mixture of drift and Coal Measure shales, the former being used in small quantities. The plant has a capacity of 25,000 building brick per day. In addition many four to twelve inch tile are made, and in the course of a year about 500,000 paving brick. One-half of the entire product is marketed outside of Fort Dodge. Convenient side tracks favor railroad shipments.

FIG. [illegible]. Two of the Fort Dodge brick plants. In the foreground are the works of the Fort Dodge Brick and Tile Company; in the background the Fort Dodge Clay Works.

Bradshaw & Moeller's yard in West Fort Dodge is located on a ravine which extends back from the river a short distance. The clay is Coal Measure shale and river silt. A Fate and Freese end cut machine with 20,000 daily capacity is used. The brick are in part steam dried and in part dried by exposure to the air under open sheds. Four down draft kilns are used for burning the brick. Eighteen men are employed from April to November.

The Kime brickyard, which was at one time operated near Fort Dodge, making a good brick from Coal Measure shale and silt, has for some time been idle.

Brickyards at Coalville.—Schnurr Brothers operate a brick

and tile plant at Coalville, using Coal Measure clay with which a little glacial drift is mixed. A section in their pit which is on the bank of the Des Moines river shows:

		FEET
4.	Drift, with some lime	6
3.	Shale	4
2.	"Coal blossom"	1
1.	Shale	12

Brick are here burned in three down draft kilns. The four inch tile made at this plant sell for $14.50 a thousand and the six inch for $27.00. Very recently Johnson Brothers have started a brick plant at Coalville with an outfit and material about like those just described.

Brickyards at Lehigh.—Excellent deposits of Coal Measure shales along Crooked creek have led to the development of the brick industry on a large scale. At present three large yards are in successful operation, and the Lehigh brick deserve the reputation that they enjoy as fine material both for interior and exterior work. Limited shipping facilities are the only handicap on the Lehigh yards. Located as they are directly in the midst of the greatest coal producing area in the county they enjoy cheap fuel.

The Corey Pressed Brick Company uses a Boyd four mould press with a daily capacity of 20,000. For brick of the first grade made at this plant $12 a thousand is received. Three round and two square down draft kilns are used for burning. The clay pit shows thirty feet of excellent shale. No glacial clay is used, and this is a prime factor in securing and maintaining the high grade of the brick produced. Much of the clay here is mined in order to avoid removing the glacial clay which overlies it, and by exercising some care in choosing the clay, brick of various attractive colors are secured.

The Lehigh Clay Works, with G. W. Hughes as president, George V. Bailey as vice president, and Fred Essleck as secretary and treasurer, commenced operations in 1900. A stiff mud machine manufactured by the American Clay Working Machinery Company, and an oscillating side cutter are in use. The kilns are of the Brighton type, and of 75,000 capacity. An abundance of

Coal Measure shale is available. An analysis of these shales, taken from the pit of this brickyard, is as follows:

	PER CENT.
Silica	53.08
Iron oxide	6.64
Alumina	17.71
Lime	4.05
Magnesia	.94
Carbonic acid	2.53
Soda	3.70
Potash	1.25
Water in combination	6.77
Undetermined	1.33
	100.00
Insoluble in sulphuric acid and sodium carbonate	71.55

Beem and Wilson are making preparations to start the old Lehigh brickyard, some time ago partially destroyed by fire.

FIG. [illegible]. The Fort Dodge Pottery

Fort Dodge Pottery.—This industry has passed through a gradual but very satisfactory development and today is a well

established and important industry. The wares produced are jugs, jars and butter crocks. Many large pieces of twenty to thirty-five gallons capacity are made. The clay used in these articles is obtained from a mine in the Coal Measure shales on the left bank of the river, a half mile above Fort Dodge. It burns uniformly and there is but little loss from checking or cracking. Fort Dodge plaster, about twenty tons a year, is used for the moulds. Considerable skill is shown in the glazing, and the appearance of the ware put on the market is attractive. The annual output is valued at $30,000.

Below two analyses of clay are given, the "first quality" being in constant use at the Fort Dodge pottery, while the second, which is equally available so far as supply is concerned, proves to be a clay which checks badly in burning.

	FIRST QUALITY.	SECOND QUALITY.
Silica (SiO_2)	66 00	63.83
Alumina (Al_2O_3)	19.32	17 55
Iron oxide (Fe_2O_3)	.80	2.75
Calcium oxide (CaO)	2 85	2 94
Magnesium oxide (MgO)	.54	.57
Potash (K_2O)	1.15	.67
Soda	2.49	.79
Carbon dioxide	.....	2.36
Water and undetermined	6.84	8.54
	100.00	100.00
Insoluble in H_2SO_4 and Na_2CO_3	58.55	68.69

Clay number one is a good pottery clay, as will be seen by comparing it with the analysis of pottery clay from Zanesville, Ohio, given below, which enjoys a wide reputation. The low percentage of iron prevents discoloring and the small quantity of water ensures the material against checking.

ZANESVILLE, OHIO, POTTERY CLAY.

	PER CENT.
Silica (SiO_2)	64.26
Alumina (Al_2O_3)	22.95
Iron oxide (Fe_2O_3)	1.28
Calcium carbonate ($CaCO_3$)	.45
Magnesium oxide (MgO)	.37
Potash (K_2O)	1.81
Soda	.15
Water	8.79

A careful search for a clay that would furnish a good fire brick was made but without success. The clay lying directly under the gypsum seemed to be the material sought, but an analysis showed a high percentage of powerful fluxes, so that the high silica content, which is favorable, is in part overcome. The analysis is as follows:*

	PER CENT.
Silica ($Si O_2$)	79.99
Alumina (Al_2O_3)	7.49
Iron oxide (Fe_2O_3)	.47
Calcium oxide	2.09
Magnesium oxide (MgO)	2.37
Potassium oxide ($K_2 O$)	2.88
Water	.49
Rational analyses	4.45
	100.23
Insoluble in $H_2 SO_4$ and $Na_2 CO_3$	84.66

The analysis indicates that in burning this clay will require little fuel, but will demand more than ordinary care on account of the narrow margin between incipient and final fusion, the percentage of fluxes being high.

Building Stone.

The Saint Louis limestone has furnished a great deal of valuable building stone, much of which has been used for foundations and terrace walls in Fort Dodge. Most of the stone has been quarried along Soldier and Lizard creeks, and near the left bank of the river, at numerous points for two miles north of the city. Work is carried on intermittently, and at no point do the developments deserve the name of quarry, if by that term permanent fixtures in the form of derricks and heavy machinery is understood. Operations on Soldier creek have been mainly confined to Baehring's quarry, near the mouth of the creek. Here both limestone and sandstone, the latter calcareous, have been quarried for use in Fort Dodge, some of the layers being of considerable thickness and all of the stone of good quality. The excessive amount of drift, which must be removed before quarrying is possible, limits future operations at this point.

* Analysis by J. B. Weems.

Opportunities for more extensive quarries in the limestone are offered at a number of points along the Des Moines river north of Fort Dodge. The Coal Measure shales and drift have been removed by the river and the stone forms a scantily covered shelf often two hundred yards wide. The stone, however, hardly warrants extensive development if large building blocks are desired. It is very durable, but is too badly broken by joints and cracks to furnish material for heavy walls. The rapid increase in the use of Portland cement, however, has throughout the country stimulated the crushed stone industry. Building and paving with concrete are destined to increase steadily as the years go by, and the Saint Louis limestone along the river in Webster county will furnish excellent material for these purposes. The very characteristics that render it unfit for building blocks make it a most economical stone for crushing. In this use of the limestone it is reasonable to anticipate the greatest development in connection with Webster county quarries.

Quarries in Sandstone.—The Coal Measure sandstones in the southern part of the county have at various points attracted quarrymen. The softness of the stone and the fact that it generally carries enough sulphide of iron to cause it to discolor on exposure to the air have greatly discouraged extensive efforts at development. The first of considerable size was the Crawford quarry on the Albee estate, in Tp. 88 N., R. XXVIII W., Sec. 14, Nw. 1/4 of Ne. 1/4. The quarry is located in a small ravine where the rock is naturally exposed. An average section through the quarry face shows:

	FEET.
3. Drift	10 to 15
2. Shale	2 to 3
1. Sandstone	15

The sandstone is probably much thicker, but has not been quarried below the bottom of the ravine. It is ferruginous and contains many selenite scales which look like mica. Even in a given layer the stone varies often in color and hardness. The colors are various shades of red. Some layers are practically useless for building purposes because they contain many small iron concretions. At certain points in the quarry the rock attains a fair degree of hardness. The layers are of a desirable thickness,

varying from six inches to two feet. Jointing is imperfect, but sufficiently well developed to render quarrying easy. Some years ago the quarry was well equipped with steam derricks, and a side track gave good shipping facilities, but at present it is not operated.

The Carter, Laufersweiler and Ryan sandstone quarry is situated in Washington township, Sec. 26, Se. ¼, on the river bank, and close to the tracks of the Lehigh branch of the Mason City & Fort Dodge railroad. At present only a few feet of drift must be removed to render quarrying possible, though as work extends back into the bluff the amount will gradually increase. At present the face of the quarry shows twenty feet of gray and red sandstone, with the colors arranged in no definite order. The gray stone is often three feet thick, is not in well defined layers, and scales off into the red. The particles of sand in the gray stone are cemented with calcareous matter, while the uniting element in the red is iron. The fact that the gray stone effervesces with acid does not in any way indicate lack of durability. It is the most promising sandstone quarried up to this time within the county, although it has not been found as yet in quantities sufficient to justify extensive quarrying. A few men are kept profitably at work, however, and most of it is trimmed at the quarries into attractive sills and trimmings for brick structures.

If suitable shipping facilities were present, the sandstones exposed along the river in the northern part of the county would warrant careful investigation. They appear to be harder, of good color and are as a rule more nearly [illegible] than those south of Fort Dodge.

Portland Cement

In the development of the natural resources of the United States during the past five years, nothing has been more phenomenal than the progress made in the manufacture of Portland cement. The first attempts to make cement in America date back to [illegible]. In [illegible] the country produced only [illegible],000 barrels, while [illegible],000 were imported. Since that time progress has been more rapid, but the demand for Portland cement has increased

even more rapidly, and the deficiency has been made up by importation, as is shown by the following table:*

	AMERICAN.	FOREIGN.
	Barrels.	Barrels.
1882	85,000	370,400
1885	150,000	554,396
1887	250,000	1,514,095
1892	547,440	2,440,654
1894	789,757	2,638,107
1896	1,543,023	2,989,597

Since 1898 many new mills have been erected. In Michigan and Illinois especially the production of cement has greatly increased; yet during the ten months ending in April, 1900, cement valued at $2,617,470 was imported.† It appears that the rapidly increasing supply lags nearly as far behind the increased demand as formerly. The time will doubtless come when supply and demand will be more nearly balanced, though the danger of over supply seems remote. In locating new mills, however, the fact must be kept in mind that competition will be sharper in the future, and conditions as favorable as possible for economic production must be sought. The plant, too, must be large enough to allow great economy in management. Under favorable natural conditions would be included an abundance of high grade raw material, cheap fuel, good shipping facilities and a convenient market.

The materials used in making Portland cement are a pure limestone or marl, and clay or shale. About three parts of limestone are used to one of shale. These materials are ground, burned together at a high temperature and then reground. It is very essential that the limestone be free from magnesia, and this greatly limits the number of available limestones. The following description of suitable clays for Portland cement is taken from an article by W. H. Hess in the Cement and Engineering News for February, 1900:

* Cement and Engineering News, Vol. VIII, No. 1, p. 13
† Ibid, June, 1900, p. 91.

	SECONDARY CLAY.	PRIMARY CLAY. I.	PRIMARY CLAY. II.
Silica	39.63	68.24	68.81
Alumina	11.40	20.60	18.01
Iron	4.59	6.08	6.13
Oxide of lime	13.78	0.01	0.98
Oxide of magnesia	5.19	0.24	0.10
Sulphuric anhydride	1.62	0.01	0.12
Loss on ignition	23.83	15.40	7.44

A secondary clay is not an ideal clay, but it can be used. Its disadvantages are: (1) High content of magnesia and gypsum; (2) the high percentage of lime will make frequent analyses necessary; (3) the temperature of calcination may be variable, and therefore, high; (4) in case transportation from a distance is necessary, 20 per cent of the weight is not clay.

Primary clay, No. I, is an ideal clay. It will combine with carbonate of lime at a comparatively low temperature; it will, therefore, be economical in the amount of fuel required for the calcination of the cement. It has a disadvantage in rotary practice that underlimed sticky clinkers and the fused mass interferes with the burning. With this clay careful chemical work is necessary, and the temperature of calcination must be carefully controlled. It will give the best cement at the least cost, when properly handled.

Primary clay, No. 2, is an economical clay for transporting long distances. It will not be economical, in fact, for the temperature of calcination of the clinker must be high. The clinker will not fuse in the [illegible] [illegible], even though the content of lime varies. [illegible] without necessitating careful chemical control of the mixture of raw materials, and the calcination need not be so troublesome. As the industry progresses and competition becomes keen, this clay will be replaced by a clay that is higher in per cent of alumina and lower in percentage of silica [illegible] of constant composition will become necessary, and the temperature of burning will be gauged so as to be as low as possible without sacrificing the quality of the cement produced.

An analysis of chalk used in the manufacture of Portland cement at White Cliffs, Arkansas, which may be taken as typical for suitable lime for cement, is as follows:

Carbonate of lime	[illegible]
Carbonate of magnesia	[illegible]
Silica	[illegible]
Alumina, iron oxide	[illegible]
	[illegible]

This combination would be improved if the magnesia were [illegible] absent. [illegible] the magnesia [illegible] [illegible] per cent [illegible] the cement.

[illegible] analysis [illegible] limestone and [illegible] shale

taken from the exposure at the mouth of Lizard creek on the right bank, gave the following results:*

Upper layer, 2 feet.
  Carbonate of lime 88.75.
  Sulphate of lime 00.28.

Next layer, 2 feet (shale).
  Carbonate of lime 53.25.
  Sulphate of lime 2.46.

Next layer, 2½ feet.
  Carbonate of lime 88.75.
  Sulphate of lime 00.17.

A sample of cement was made from these layers and carefully analyzed, with results as follows:

Lime	63.48
Silica	25.53
Alumina and iron	8.80
Magnesia	1.19

The cement was pronounced excellent by experts, and the locality was reported as worthy of careful investigation with a view to the erection of a cement mill. A more favorable locality may be found on the Des Moines river above Fort Dodge, where the Saint Louis limestone is more abundantly exposed, and where the Coal Measure shales are available. In view of the fact that better localities in Iowa have not yet been reported, the conditions in Webster county should be borne in mind by those interested in establishing a cement mill in the state. Fuel is abundant and cheap, and four great railroad systems give direct connection with all parts of the country. The reputation that Fort Dodge already enjoys as a plaster producing center would be in favor of the new material when put upon the market.

Lime.

Formerly limited quantities of the Saint Louis limestone were burned for quicklime along the Des Moines river and Soldier creek. On account of the chemical composition of the stone it is not possible to make from it a high grade of lime. A magnesian limestone is necessary in order to produce a lime that will

* Analyses by Lundteigen, of the Peerless Portland Cement Company.

not too readily slake, and that will bear shipment and attendant exposure to the air. As has been shown, however, the absence of magnesia gives the stone a greater economic value in making it suitable for Portland cement.

Road Materials.

In the gravel terrace along the Des Moines river there are great quantities of excellent road material in the form of sand and gravel. These terraces are remarkably developed at points near Fort Dodge on both sides of the river. This is particularly fortunate, for in the central and southern part of the county there is much flat land that is but partially drained. In the northern part of the county numerous gravel pits have been opened up in the kames that are found in the morainic tracts already described. The location of gravel pits is shown on the accompanying map. The Saint Louis limestone, if crushed, would make a good macadam, and immense quantities of it are available. The bowlders scattered over the fields and piled in fence corners, if broken and placed on the roads as is the custom in northern Germany, would greatly improve existing conditions.

Water Power.

At present water is not used for power at any point within the county, though traces of a number of dams still remain along the Des Moines river. A head of six or more feet could easily be obtained at a number of points on the river without flooding the arable lowlands. During the greater part of the year at least thirty horse power could thus be secured. During the three summer months the power would be reduced one-half. Until fuel becomes more expensive, however, it will hardly be practical to utilize the water power within the county for anything except minor enterprises.

Water Supply.

Most of the farm wells obtain water in sand layers within the glacial drift. The supply so obtained is generally abundant and the depth to which the well must be sunk is not excessive, vary-

ing from ten to sixty feet. In the northern part of the county a few wells find water in the Saint Louis limestone, while in the southern part some wells penetrate the Coal Measure shales till a sandstone layer is reached. The water of these wells is apt to carry iron in solution. Water in deep wells in the gypsum area is often impregnated with that mineral. No unusual difficulties are encountered in well drilling. The average price for drilling in the northern portion of the county is fifty cents for dirt and $1.50 for rock, for the first hundred feet, and twenty-five cents per foot additional for greater depths. There are no flowing wells in the county. Excellent springs are found in the bed of Lizard creek, one mile above its mouth, the water coming up through cracks in the Saint Louis limestone. Near the mouth of Prairie creek are small perennial springs. Water for the city of Fort Dodge is taken from the Des Moines river by means of filters placed at the upper end of Duck island. The water is potable and reasonably pure.

Mineral Paint.

The color of many of the clays in Webster county, especially those found just above and below the gypsum, has led many persons to experiment with them with the hope of finding a natural pigment. In a limited measure their hopes have been gratified for at times the clay carries sufficient iron oxide to render it good paint when ground and mixed with oil. It has not proven satisfactory enough to warrant extensive development, however, and no pigments of commercial importance can be reported as occurring in the county.

Mineral Springs.

While many wells, particularly those within the gypsum region, yield water which contains a small amount of mineral matter in solution, but one highly mineralized spring was found within the county. Located on the right bank of the Des Moines one-fourth of a mile above the bridge at Kalo, in Tp. 88 N., R. XXVIII W., Sec. 17, center, is a perennial spring of considerable volume yielding non-potable water. A chemical analysis made by Professor Weems shows that this water contains:

Alumina, Al_2O_3 .... [illegible] parts per million
Ferric oxide, Fe_2O_3 .... [illegible] parts per million
Sulphur trioxide, SO_3 .... [illegible] parts per million

The alumina and iron are probably present as sulphates, and the impression that the water gives to the taste is that of a strong alum solution.

The amount of alum present is insignificant from an economic point of view, and while sulphate of iron under the name of copperas is used freely in the arts, it is produced so cheaply as a by product in the manufacture of wire that an attempt to obtain it by concentration of spring water would not prove remunerative.

Minerals.

Selenite.—The massive and fibrous gypsum of Webster county has already been described. The crystalline form, selenite, deserves further notice. It occurs commonly in the Coal Measure shales and is found also in smaller quantities in the marly layers of the Saint Louis limestone in [illegible] county. The crystals are often remarkably perfect in form and transparency. [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] united along the [illegible] [illegible] impurities are often arranged along the common axis [illegible] which [illegible] project parallel to the [illegible] axis. Simple crystals are commonly twice as long as broad, with a thickness equal to half their breadth. Small crystals of [illegible] have been reported [illegible] [illegible] [illegible] [illegible] of Fort Dodge, but the mineral is exceedingly rare.

Iron Ore.—Limited quantities of limonite are found in the Coal Measures of the southern part of the county. The highest grade is found in [illegible] rock, at the [illegible] [illegible] [illegible] forms the cementing element in a fine conglomerate. On the [illegible] south of Fort Dodge, near the [illegible] [illegible] [illegible] [illegible] of limonite [illegible] [illegible] occurs. [illegible] [illegible] [illegible] [illegible] [illegible] present in quantities sufficient to render it of economic importance.

Pyrite and Marcasite.—[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] in the nodules of the Coal Measures [illegible] [illegible] [illegible] beautifully crystallized [illegible] [illegible] [illegible] [illegible] [illegible]

ments of the Coal Measure flora have been replaced by them. The fossils containing marcasite unfortunately soon crumble on exposure to the air.

Cone-in-cone.—In a cutting on the Lehigh branch of the Mason City and Fort Dodge railroad, just above Duncomb's mill, a layer of cone-in-cone eight inches thick may be traced for a hundred yards. This mineral when found in detached fragments is often thought to be petrified wood on account of its fibrous structure. The fibers of the mineral are arranged in bundles in the form of a cone, and when the outer layers are removed, an inner cone appears. Cone-in-cone has previously been reported from Iowa by Owen* and Beyer.† Chemical analysis by Professor G. E. Patrick showed that it is nearly pure calcium carbonate ($Ca\,CO_3$, equalling 83.12 per cent). Calcium carbonate in its ordinary crystalline form, calcite, is not common. Small crystals are sometimes found in cavities in the Saint Louis limestone.

Celestine.—This mineral, the sulphate of strontium ($Sr\,SO_4$), has been found in at least two localities in Webster county in limited quantities. In 1896, near Kohl's brewery at the mouth of Soldier creek, a mass of fine crystals was taken out of the shales overlying the gypsum. It has within recent years been reported from the vicinity of the old packing house on the left bank of the river just below Fort Dodge. White‡ mentions both of these localities and says that celestine has been found in Webster county both in the Coal Measure shales, and in the clays that overlie the gypsum. The layers found by him were not more than a rod in length and three inches in thickness. In all cases the mineral is light blue in color and nearly transparent. Strontium is sometimes obtained from it, but it must occur in large quantities to possess commercial value.

Copperas or Ferrous Sulphate.—($Fe\,SO_4$) On the face of the sandstone ledges in Prairie creek a white powder forms, which is washed off by the rains only to reform within a few days. Instead of powder there are at times slender, white, needle like crystals. Both crystals and powder are the sulphate of iron or copperas as it is commonly called. Massive crystals of copperas

* Geol. Iowa, Wisconsin and Minnesota, p. 123.
† Iowa Geol. Surv., Vol. V, p. 231.
‡ Geol. of Iowa, White, 1870, Vol. II, p. 304.

are said to have been found at the old coal mines above Fort Dodge.

Aluminum Sulphate.—(Al_2 SO_4.) This mineral was found filling small cavities and forming small layers in the Coal Measure shales exposed along the Des Moines river below Lehigh. It occurred in the form of a brown powder. At no point was it found in considerable quantities, though a few pounds could be obtained readily.*

Tufa Beds.—Near the mouth of a small ravine on the right bank of the river, one-half mile above Lehigh, in Burnside township, Sec. 1, Sw. ¼, there is an extensive deposit of calcareous tufa. The deposit covers to a thickness of several feet the Coal Measure sandstone that forms the bank of the hollow. It contains innumerable beautifully preserved impressions of leaves of the hardwood trees now common to the locality, as well as shells of Mesodon.

It is doubtless the result of an extensive lime bearing spring and the material has recently been deposited, though no spring now exists in the locality.

Soils.

With but trifling exceptions, the soil of Webster county is glacial in origin. It is rich in lime and generally effervesces with acid vigorously from the grass roots down. It yields most abundant crops of the grains and fruits that the climate permits. The surface is but seldom covered with more bowlders than are desirable for the construction of foundations for farm buildings. On the lower river terrace the silt makes a very desirable soil.

Prehistoric Inhabitants of Webster County.

Relics of people that inhabited the country at a period much earlier than the advent of the white man, have from time to time been found, and have always attracted a great deal of popular interest. Conspicuous mounds in the vicinity of Lehigh have long been recognized as the work of the mound builders, and

* Analysis was made by Prof J. B. Weems.

those that have been opened have yielded fragments of decorated pottery, portions of human skeletons and arrow points.

A locality which has of late years attracted considerable attention on account of its relics of prehistoric age is "boneyard hollow." This is the name given to the mouth of a ravine two and a half miles above Lehigh, on the right bank of the river. The river here develops two terraces, shown in the sketch as T 1 and T 2. On the south bank of this ravine, in the second terrace, bones, arrow points and bone ornaments in considerable numbers have been found. The width of the ravine here is considerable, perhaps a hundred yards. The bones are those of buffalo, and with the exception of the teeth, which are abundant and well preserved, are badly decayed. They are buried under six feet of silt and above them trees of considerable size are growing, among others a hard maple twelve inches in diameter.

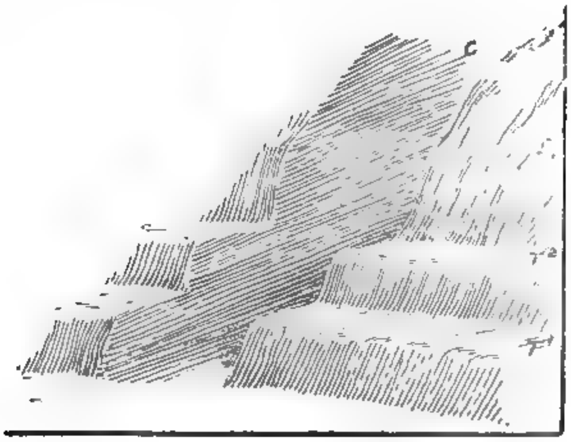


FIG. 27. Sketch of the ravine and terraces at "Bone Yard Hollow"

Shells of Mesodon are common in the silt. With the bones a double ring was found, in pattern like two of the three rings in the Odd Fellows' symbol. They were skillfully carved out of bone, probably the tip of a buffalo horn, and each is an inch in diameter.

If these relics are considered as old as the terrace T 2 in which they are found, their antiquity is considerable and some importance must be attached to them. Unless, however, similar relics are discovered far back in the terrace, away from the edge to-

25

BY

those that have been opened have yielded fragments of decorated pottery, portions of human skeletons and arrow points.

A locality which has of late years attracted considerable attention on account of its relics of prehistoric age is "boneyard hollow." This is the name given to the mouth of a ravine two and a half miles above Lehigh, on the right bank of the river. The river here develops two terraces, shown in the sketch as T 1 and T 2. On the south bank of this ravine, in the second terrace, bones, arrow points and bone ornaments in considerable numbers have been found. The width of the ravine here is considerable, perhaps a hundred yards. The bones are those of buffalo, and with the exception of the teeth, which are abundant and well preserved, are badly decayed. They are buried under six feet of silt and above them trees of considerable size are growing, among others a hard maple twelve inches in diameter.

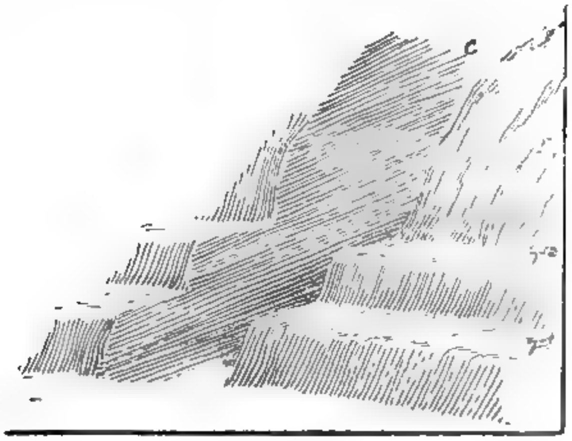


FIG. 27. Sketch of the ravine and terraces at "Bone Yard Hollow"

Shells of Mesodon are common in the silt. With the bones a double ring was found, in pattern like two of the three rings in the Odd Fellows' symbol. They were skillfully carved out of bone, probably the tip of a buffalo horn, and each is an inch in diameter.

If these relics are considered as old as the terrace T 2 in which they are found, their antiquity is considerable and some importance must be attached to them. Unless, however, similar relics are discovered far back in the terrace, away from the edge to-

BY

ward the river and ravine, it is much more natural to suppose that the bones and implements accumulated where they are now found and were afterward covered by material washed down upon them from points higher up on the terrace. Shells of Mesodon abound at higher points and might easily have been washed down, with earth and sand, over the old camp fire of Indians who sought the edge of the ravine for shelter from the wind. It would not seem wise, therefore, to ascribe to them great antiquity. The bone rings, too, are of a pattern which Indians and mound builders did not know, and which suggests contact with white men.

ACKNOWLEDGMENTS.

In the preparation of this report the writer is indebted to many persons. He enjoyed the company of Professor Calvin in visiting the typical drift exposures of the county, and in determining the age of the drift was aided by his judgment. In the discussion of the age and origin of the gypsum the aid and influence of Professor T. C. Chamberlin is gladly acknowledged. Dr. H. F. Bain spent some time in the field searching for suitable material for Portland cement. Dr. Charles R. Keyes' previous report on the Webster county gypsum was of service at many points. Prof. Macbride identified the ferns and other representatives of the Coal Measure flora. Mr. A. W. Ristine, a student at Harvard, carried out successfully many details of the field work in the summer of 1900. The various well drillers whose names are given in connection with data cited were generous and courteous in furnishing this valuable information. The managers of the various coal companies contributed important facts which go far toward making the report complete.

THE GYPSUM INDUSTRY

OF

GERMANY.

THE GYPSUM INDUSTRY OF GERMANY.

During the past ten years the German gypsum industry has made rapid advances. In amount of money invested, in the quantity of the output, in development of machinery and in the variety of uses to which the manufactured products are put, it surpasses the gypsum industry of the United States. This may be accounted for in part by the fact that the chemical and physical properties of gypsum have been more carefully studied in Germany. The demand for more permanent and fireproof building material than is commonly used in America has doubtless been an additional stimulus to the gypsum industry of Germany. On the other hand, the industry in the United States has developed certain valuable characteristics to meet the peculiarities of the American manner of building which are unknown in Europe. Before its recent rapid progress the German gypsum industry underwent a long and gradual evolution. Gypsum plaster was used in many of the old feudal castles, many of which are still standing, and are cited as a proof of its durability. The first grinders of gypsum rock were the millers and the first calciners were the bakers. Traces of these original processes may be seen in many of the methods employed today. Early efforts at economy in fuel were made by those who endeavored to calcine gypsum with the waste heat of the lime pit. Indeed, in some parts of the country these primitive processes linger, and contrast strikingly with a modern mill like that of the Rhenish gypsum industry at Mannheim where fuel and labor are economized by continuous rotating calciners and where the mill is walled, floored and roofed with gypsum plasters.

The German gypsum industry has three great centers; the Hartz mountains north of Nordhausen, about the village of Ellrick; in Thuringia, near Possneck, in the village of Krolpa; and at various towns on the Rhine, near its confluence with the Neckar.

With one of two exceptions, the mills are located near the gypsum beds. These exceptions are instances where the raw material is brought nearer to market and to fuel by river boats.

The industrial conditions differ somewhat from those in America. Labor in quarries, mines and mills is paid about one-half as much as service of the same sort would receive in the United States. Fuel, on the other hand, which in the manufacture of gypsum plaster is secondary only to labor, costs more than twice as much. The price received for plaster is much less than in America, and competition for trade is stronger. An annual meeting of the gypsum manufacturers regulates prices. In a measure this meeting is also beneficial by reason of its discussion of new processes in manufacturing and new uses for the products. At the last meeting, which was held at Berlin, it was proposed that all mills unite in publishing circulars and a magazine, to go to the building trade of Europe, making plain the many uses to which gypsum plaster may be put.

In preparing this report the chief mills in Thuringia, on the Rhine and at Ellrick in the Hartz, were personally visited. German literature bearing on the subject was, as far as possible, carefully studied. Out of date processes which were found in operation or described in the text-books will not be here discussed. An effort has been made to make the report practical and not load it with matter which will be of no value to the American manufacturer. Those who care to study the German industry farther will find the books and magazines given below useful:

1. Der Gips und seine Verwendung, Handbuch fur Bau und Maurermeister, Stuccateure, Modelleure, Bildhauer, Gipsgiesser, u, s, w, von Marco-Pedrotti, mit 45 abbildungen; Vienna, Pest, Leipsig, A. Hartleben's verlag, 1901.

2. Handbuch der Baustofflehre, fur Architekten, Ingenieure, und Gewerbetreibende sowie fur Schuler Technischer Lehranstalten; von Richard Kruger, in zwei banden mit 443 abbildungen; Vienna, Pest, Leipsig, A Hartleben's verlag, 1899.

3. Prometheus, Illustrirte wochenschrift uber die fortschritte in Gewerbe, Industrie, und Wissenschaft, herausgegeben von Dr. Otto N. Wirt, verlag von Rudolph Muckenbuger, Berlin XII Jahrgang, 1900, Nr. 583, 584 und 602.

KINDS OF GYPSUM PLASTER USED IN GERMANY.

In this report the kinds of gypsum plaster used in Germany will be first described, followed by an account of the various methods used in milling and calcining. Crushed and ground gypsum in four distinct forms is put upon the market. These are stuck gypsum, estrick gypsum, porcelain gypsum and dunge gypsum. These four sorts of gypsum are prepared by different methods and are used for different purposes.

STUCK GYPSUM.

By this name the Germans recognize gypsum that has been heated to a temperature of about 300° Fahrenheit (147° C.) and has lost 14 per cent of its water of crystallization. It is ground either before or after this process of calcining. It is practically what is known in America as calcined plaster. In Germany as in the United States stuck gypsum is used chiefly as a covering for interior walls, but on account of fundamental differences in the ordinary methods of building in the two countries, the manner of application is very different. It is also used for purposes to which it is not applied in the United States.

Stuck gypsum (calcined plaster) as material for covering interior walls.

1. As covering for lath. Very little wood is used in building the walls of a German house. The reason for this is twofold:

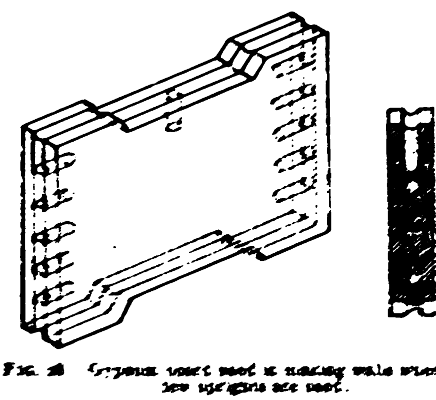


FIG. [illegible] Gypsum [illegible] used in making walls where [illegible] uprights are used.

wood is expensive and, moreover, the German seeks to make his buildings as nearly fireproof as possible. For this reason inte-

rior walls made of wooden uprights covered with lath and mortar, do not appeal to him as suitable building materials. Yet this kind of wall is not unknown in Germany. When gypsum is employed in making mortar to cover such walls two parts of sand are added to one part of gypsum. No hair or retarder is used.

2. Mortar for interior brick walls.* Another mixture in great favor in Germany as wall plaster consists of three parts quick lime, one part calcined plaster and one and a half parts fine white sand. This is the common mortar employed to cover interior brick walls, which are general in Germany. This plaster is often made smooth by subsequently covering the surface with a coat of gypsum and lime water, and rubbing with sandstone, tripoli and felt. A polished wall surface is also secured in a

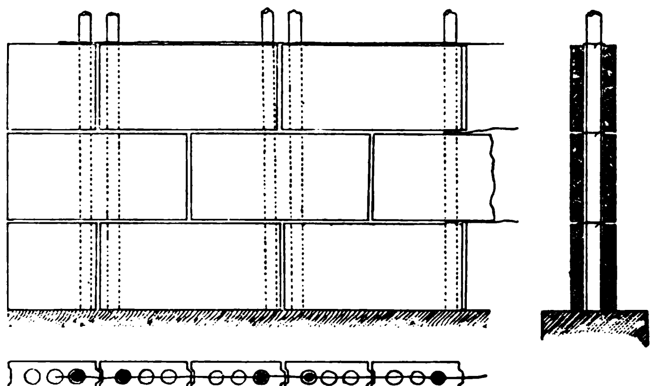


FIG. 23. Gypsum boards fastened together with cement or gypsum rods.

somewhat similar manner. After the plaster has been washed with the gypsum lime water mixture and thoroughly dried, it is covered by means of a trowel to the thickness of three millimeters with a coating of very fine mortar composed of lime and gypsum, to which ten per cent of fine sand or marble dust is added. This is finally rubbed over with polishing wax.

3. Mortar for ceilings. Ceilings are made by using lath or wire as a background on which to spread mortar. A composition somewhat different from that used for walls is recommended for ceilings by German builders, namely, two parts gypsum and one part sand, without any lime. When laths are used the space between them is two and one-half centimeters.

* Baustcffiehe, Kruger, (Wien, Pest, Leipsig a, Hartlebens verlag, 1899.)

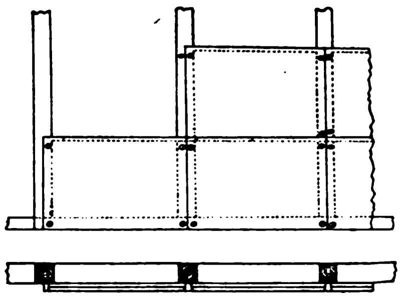


FIG. 30. Gypsum boards nailed or screwed directly to wooden uprights.

4. Stuck gypsum (calcined plaster) as covering for wire walls. Stuck gypsum, lime water, hair and sand, mixed as for ordinary wall plaster, are used in Germany to cover the wire netting which takes the place of lath. The wire used is from one to one and one-tenth millimeters thick, woven with a two centimeter mesh, and held in place by angle iron or by round iron, with a diameter of one centimeter. The gypsum mortar when hard is covered with a wash of gypsum, lime and fine, clean sand. Walls so made are fireproof, are poor conductors of heat and occupy but little space. They are made both single and double.

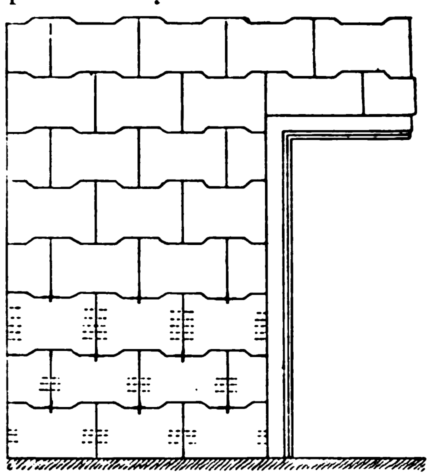


FIG. 31. A wall of gypsum boards in which no uprights are used, the boards dovetailing into one another.

When single their thickness is but five centimeters and when double, with an air space between of five centimeters, each wall has a thickness of three centimeters, making the total thickness

of both walls, with enclosed air space only eleven centimeters.

The gypsum mortar to some extent oxidizes the wire. A certain amount of such oxidation is desirable for it binds the mortar firmly to the wire. It will not proceed beyond the desirable point if the wall is normally dry. For walls which are greatly exposed to moisture some other form of construction would be safer.

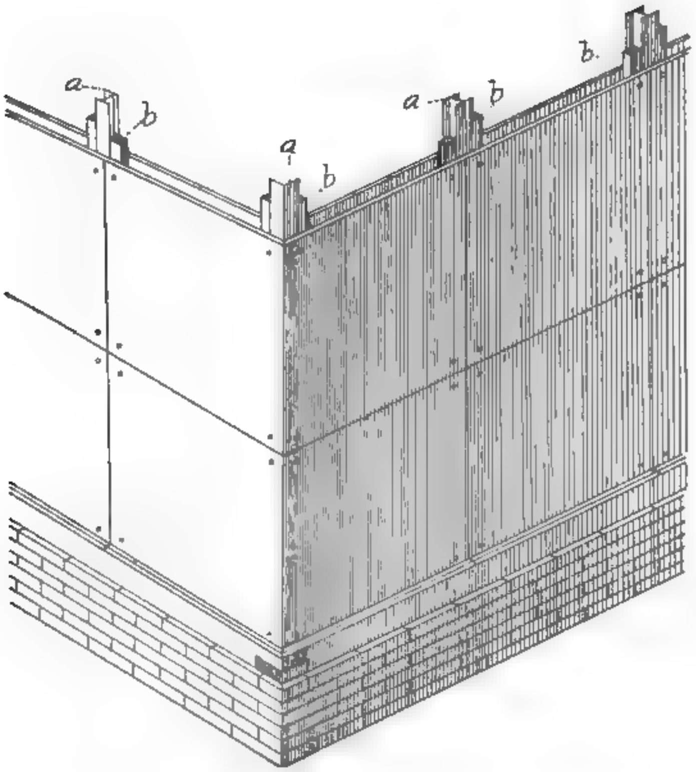


FIG. 32. Gypsum boards fastened to narrow wooden strips in iron uprights. Such a wall is practically fire proof.

Special devices in which calcined plaster (stuck gypsum) is made into boards or slabs which are attached to a framework to form an inner (rarely an outer) wall.—Under this head are included the most interesting and unique features of the manipulation of gypsum in Germany. These are practically unknown in American building methods,* and there are no English equivalents

* In New York and Chicago gypsum boards somewhat like those described here are rapidly coming into favor.

known to the writer for the German terms. In this report, therefore, for the words gypsdielen and schulfbretter, the term gypsum boards will be used. A description of gypsum boards as made at Ellrick will answer in general for many forms made both in Germany and Switzerland. Calcined plaster (stuck gypsum) is mixed with water and a certain amount of sawdust. On an iron table with a heavy iron top are laid iron strips, which have a thickness equal to that intended for the gypsum board. The space enclosed by these strips also determines the length and breadth of the board. Within this space is scattered excelsior, jute and rushes, and over these is poured the gypsum, water and sawdust mixture. The rushes and excelsior are carefully worked to the middle of the mass by hand. An iron bar is drawn over the top of the strips, leaving the surface of the mass either smooth or ridged. It is allowed to stand about five minutes, and then the iron table on which the mass rests is struck vigorously two or three times with a heavy mallet. This loosens the gypsum board from the iron plate and strips. It is already so firm that it may be picked up and carried without injury. A workman takes it on his shoulder and carries it to an open shed where it stands on end till dried by natural heat. The length of time required for drying depends wholly upon the atmospheric conditions. Artificial heat for drying gypsum boards has proven very unsatisfactory, as the boards so dried crumble

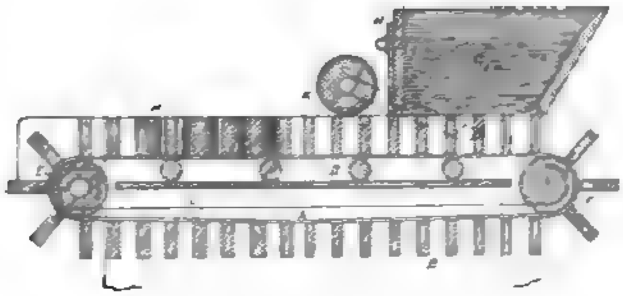


FIG. 33. Sketch of machine for making gypsum boards. (Described in text.)

readily on exposure to the air. At Ellrick elaborate attempts to dry them by steam heat have proved failures.

The Rhenisch Gypsindustrie at Heidelberg has devised machinery by which gypsum boards are made with a minimum of

hand labor. One form of this machine is shown in figure 33. It consists of an endless belt upon which are a series of strips so set that the spaces between them and the belt form a series of moulds of the size desired for the boards. This belt (A) moves in a box (C) on rollers (D) propelled by the wheels E and F. At one end of the box (C) is a case (G) in which the gypsum mortar is placed. It is fed down into the moulds on the belt as they pass beneath the case (G). By the time the filled moulds reach the wheel (E) the gypsum boards have hardened and may be safely removed. The thickness of gypsum boards varies from three to eight centimeters. Often they are made with large round air spaces within, like hollow brick, and then their thickness reaches twelve centimeters, their length varying from five to twelve feet. They are used mainly for inner walls, being fastened directly to wooden or iron stringers. When used for outer walls the outer surface is made rough while the material is still soft so that some protective covering will adhere to it. For this purpose thin white lime mixed with one-third gypsum is often used, and this is in turn covered with thick white lime without gypsum. Thin white limestone covered with thick lime water, with one-fifth Portland cement, may also be employed. This outer covering is never more than one centimeter thick. Asphalt paper is also used to render the boards impervious to moisture. The accompanying sketches, after drawing in the Handbuch der Arkitekture, show some of the forms of gypsum boards, and methods of fastening them to wooden and iron uprights.

The weight of gypsum boards 2.5 centimeters thick is about fifty pounds per square meter, and for boards 8 centimeters thick about 120 pounds. During a series of experiments made at Berlin in 1890 it was found that a weight of 100 pounds when dropped from a height of six feet upon the middle of a gypsum board produced a dent only 5 millimeters deep. The shape of the weight is not given in the description of the experiment.* The gypsum boards possess considerable elasticity. Their ability to withstand pressure is shown in the following table:

* Kruger, Baustofflehre, II, p. 47.

THICKNESS OF GYPSUM BOARD.	DISTANCE OF POINT AT WHICH PRESSURE WAS APPLIED FROM POINT WHERE GYPSUM BOARD WAS SUPPORTED, IN METERS.							
	0.75	1 00	1.25	1.50	1.75	2.00	2.25	2.50
	WEIGHT IN POUNDS SUPPORTED BY EACH SQUARE METER.							
3 Centimeters	160	100						
4 Centimeters	300	140	70					
5 Centimeters	300	250	130					
7 Centimeters	950	550	350	250	180			
10 Centimeters	1800	1040	660	464	340	260	202	
12 Centimeters	2500	1420	900	620	460	2 0	250	226

Gypsum boards are also made with both sides hardened and made smooth by oil. These are used chiefly where the walls are to be papered at once.

Another form of board which is highly recommended has a paper center. Heavy sheet paper is suspended in the center of moulds and about this the gypsum plaster is poured. This expands on hardening and the pressure so produced causes an intimate union between the paper and plaster. The moulds are made with readily detachable sides, and the boards when hardened are easily removed. Moulds are usually made so that a number of boards may be cast at the same time.

In similar moulds are made the hollow boards and all the thicker forms made with reeds or paper.

An excellent substitute for reeds and paper would probably be found in the corn stalk, or some product derived from it.

Stuck gypsum (calcined plaster) as construction material for building ornaments.—Figures and reliefs are characteristic of German architecture. When not made out of stone these ornaments consist of cement and gypsum. Gypsum ornaments are hardened, colored and made so weather proof that only close examination reveals the fact that they are not made out of solid material. The gypsum figures and reliefs cost but a small fraction of the sum which would be required to produce the same ornaments in the stone which they so skillfully simulate. The ornaments are cast in moulds of wood, metal, clay, gypsum or lime. If the ornament is simple, the mould may be in a single

piece, but if complicated the mould is made of a number of easily detachable pieces. The fact that gypsum expands on hardening, filling all of the interstices of the mold, renders it a most valuable material for making casts.

Extremely hard figures capable of taking a polish may be made by subjecting the gypsum to steam, then filling the form with the steamed plaster (stuck gypsum) and submitting the form to hydrostatic pressure. Other methods of hardening figures will be described later.

As protection against the weather the following processes are recommended: warm the gypsum object and rub the surface with a mixture of three parts linseed oil varnish and one part white wax; or, impregnate the surface with sulphur balsam, consisting of fat oil in which sulphur has been dissolved (for instance, linseed oil at 160° C. and 10 per cent of sulphur). Another mixture highly recommended for protecting the surface of gypsum building ornaments is three parts of linseed oil, lead oxide equal to one-sixth the weight of the linseed oil and one part wax. Or the surface may be bronzed and otherwise protected with metal coatings.

Mixtures containing gypsum which are recommended for ornamental purposes are: One part gypsum plaster and one part lime; four parts gypsum, three parts white chalk or lime, and one part fine sand. For white ornaments one part fine gypsum plaster, two parts white chalk, with a limited amount of lime water; for gray figures, a mixture of gypsum plaster with fine coal dust. The latter mixture gives a considerable degree of hardness, but when objects made from it are exposed to moisture and frost they fall to pieces.

Stuck gypsum (calcined plaster) used to produce effect of ivory.—The fine white gypsum powder is heated and mixed with paraffin which has also been heated to 65° to 70° C. The mass is taken out and any extra paraffin drained off. If the gypsum contains colored impurities they are made all the more conspicuous by the oil. A more vivid color may be given the mass by adding coloring matter to the paraffin.

Stuck gypsum (calcined plaster) used in making artificial marble.—The ingredients are gypsum, finely sieved and burned lime-

stone, and coloring matter. Lime is used in only limited quantities and its function is simply that of a retarder so that the mass may not set within thirty minutes. The mass is worked up in a ball, the coloring matter being worked through in streaks, like the veins in marble. The ball is cut with wire into slabs, which are placed at once upon the wall or over the surface to be covered. When the surface has hardened it is smoothed with pumice and rubbed with a thin solution of gypsum, which closes any pores. It is then rubbed with tripoli and olive oil and finally polished with a woolen cloth. Earth colors are suitable for this purpose, and also any used by the frescoers which are not destroyed by lime. A great many processes for producing marble-like effects with gypsum plaster have been patented in Europe. One of the most recent was issued to Pietro Viotti. In this process 1500 grams of borax and 150 grams of magnesia are fused together, and when cool mixed with seventy-five kilograms of gypsum.

Other imitation marbles and hard cements in which stuck gypsum (calcined plaster) is used.—The following cements, in which gypsum is the chief ingredient are alike in their essential properties. They are usually hard, durable, uniform in structure, set slowly and take a high polish. They may be fastened in thin slabs to nearly any kind of background, do not crack in drying and admit of an admixture of coloring matter without loss of strength. They stand in hardness about one-half way between Portland cement and ordinary stucco.

1. Keene's cement or English white cement is a slow setting alum gypsum. Gypsum, preferably a white variety, unground, is burned at a red heat, then soaked in an alum solution, burned a second time at a red heat, and then finely ground. When used it is mixed with an alum solution. If it is used with 20 per cent water, it has a tensile strength of seventy pounds and a crushing strength of 800 pounds per square centimeter.

2. Parian cement consists of 44 parts stuck gypsum (calcined plaster) and one part calcined borax. The gypsum is saturated with water having the borax in solution and burned at a red heat. It sets slowly and dries in five or six hours. It is used as a covering for both inner and outer walls and may be painted or cov-

ered with paper. It should be mixed with as little water as possible, and must not come in contact with fresh lime.

3. Scagliola is a mixture of finely burned gypsum, ground selenite and lime-water, often made into slabs and used for wall decoration.

4. German marble cement is like Keene's cement, but possesses greater hardness, having after four weeks a tensile strength of ninety-six pounds and a crushing strength of 850 pounds per square centimeter, when made up with 20 per cent of water. It is used for the most part for outside facades, and must be protected on the weather side against rain by a coating of varnish. It is made by the Walkenruder Gyps Fabrik at Walkenried in the Hartz.

ESTRICK GYPSUM.

Estrick gypsum differs materially from gypsum plaster of any form known in America, both in its properties and method of preparation, unless the "secret process" used in the Best Brothers mill in Kansas produces it. The German name, therefore, for this sort of gypsum plaster will be used in the following description. In preparing estrick gypsum, gypsum rock is heated for a number of hours at a temperature in the neighborhood of 500° C., in a kiln which will be described later. It is ground coarse, and when mixed with water without any admixture of sand or coal ashes, it very slowly sets and forms an extremely hard mass. Its hardness makes it a suitable material for floors, taking the place of Portland cement and often rendering better service.

Floors made of estrick gypsum have as a bedding sand, coal ashes, brick or wood.

Estrick gypsum reaches its full hardness only when allowed to dry protected from moisture, and for this reason care must be taken to secure a proper foundation. Cracks will appear if it dries unevenly or very rapidly and in this case the surface must again be covered with water till it is soft and the cracks close. The mass must then dry again. After standing about twelve hours and becoming fairly hard, it is pounded with wooden mallets and smoothed with trowels. The pounding materially increases the hardness. In German texts on building

material, estrick gypsum is especially recommended as floor material for factories, kitchens, granaries, store rooms and, when suitably colored, for bathrooms and hospitals.

Pure estrick gypsum is considered best for these purposes, but if for economy this is impossible, one-third pure quartz sand or coal ashes may be used. With estrick gypsum marble may be imitated and a very hard as well as ornamental stone is the result. It may be polished with sand or sandstone, then with pumice and water. After rubbing with wax dissolved in alcohol, it is polished again with stiff brushes.

An addition of Portland cement to the estrick gypsum has at times been recommended to increase the hardness. This, however, is generally regarded as useless.

A cubic meter of hardened estrick gypsum weighs about 2,000 pounds.

The following methods of applying estrick gypsum to floors is recommended by German authors. A bedding of sand 5 centimeters thick is first laid down. If sand is expensive, this may be reduced to 3 centimeters. On this the estrick gypsum mortar is spread to a thickness of 3 centimeters. In preparing the gypsum mortar a box about 1.8 meters long, 1.2 wide and 0.4 high is used. In this box the gypsum is mixed with water till a thick mortar is formed. The water is placed in the box first and into it the gypsum is poured. The gypsum mortar so made is laid on the sand foundation in the following manner. At a distance of three feet from one of the walls a wooden strip in thickness equal to that of the desired estrick layer, is placed parallel to the wall. Between this and the wall the gypsum plaster is poured. After the water in the mortar has in part soaked into the sand and in part evaporated, the mortar is rubbed over with a steel bar and partially smoothed. Perhaps an hour later it is rubbed over again and made still smoother. Then the wooden strip is removed to a distance of three feet and the process repeated. The edge of the part previously prepared is beveled or hollowed so that the new strip may lap over it and become definitely a part of the one already made. At the end of twenty-four hours the floor will be so hard that the foot of an adult makes no dent in it. It is then vigorously tamped till water again appears on the surface. Finally it is smoothed with a steel bar.

For floors of dwellings a thickness of 3 centimeters for the gypsum covering is regarded as sufficient. For granaries 5 centimeters is recommended. For one square meter of estrick floor, 3 centimeters thick, 100 pounds of gypsum are sufficient. In Germany the cost of a square meter of sand 5 centimeters thick is estimated at three cents, the gypsum for a 3 centimeter coating at twelve cents, and labor at eight cents, making a total cost per square meter of twenty-five cents, or about twenty-two cents per square yard.

Mortar for masonry.—That gypsum will furnish an extremely durable mortar under certain conditions is fully recognized in Germany. Many old castles, towers and walls that are well preserved today are held together by gypsum mortar. An example often referred to in German literature on gypsum is Walkenried in the Hartz. In this same district, where gypsum is very abundant, tall chimneys for factories are constructed with gypsum mortar. An inner-lining of fire brick is essential, as well as an outer wall of regularly set stone. Between these rocks are placed irregularly and over them gypsum mortar is poured, filling the spaces between the blocks. The mortar, which is formed of two parts gypsum and one part sand and one part soft water, is not used for the foundation of such chimneys for it crumbles wherever it is continually exposed to moisture.

In the German texts which treat of gypsum, for instance Kruger's Baustofflehre, estrick is recommended unconditionally for masonry, and its ability to withstand the weather is positively affirmed. The manufacturers who were consulted, on the other hand, indorsed it chiefly for interior work.

Mack's gypsum cement consists of estrick gypsum to which 0.4 per cent calcined Glauber's salts (Na_2SO_4) or potassium sulphate (K_2SO_4) have been added. This cement is unusually hard and durable, sets quickly and unites minutely with the material on which it is placed. It is used as a covering for wire mesh on walls and ceilings as well as for floors and may be mixed with sand or ashes. Its surface is but slightly porous and for this reason absorbs but little oil when covered with paint.

FORCELAIN GYPSUM.

In the German porcelain industry great quantities of gypsum are used. It is prepared in a special manner and has properties differing from those of other varieties of gypsum. It is ground exceedingly fine, and after setting is much lighter than ordinary wall plaster or stucco, and is much more porous. On account of this latter property it is particularly adapted to the part assigned it in the porcelain industry. Nearly every piece of porcelain receives its shape in a mould, which may be made out of clay, wood, wax or metal, but for most of them gypsum is used. Its peculiar property of drawing out the water from the surface of the clay gives gypsum special value for this purpose. Although the surface of the gypsum moulds is made as hard as possible by rubbing with oil, the sharp edges necessary to insure accurate casts wear off, and from time to time the mould must be discarded and replaced by a new one which is made from an original clay model. A hundred imprints may be made from an ordinary gypsum mould. If the pattern is intricate the number is less. Thus a single porcelain factory consumes a great quantity of gypsum and many mills are engaged in supplying gypsum for this industry alone. The chief centers of the porcelain industry are about Dresden and in Thuringia.

DUNGE GYPSUM (LAND PLASTER)

Dunge gypsum is, as the German name implies, gypsum prepared for use as a fertilizer. As in America, gypsum for this purpose is merely ground, and not calcined. Considerable quantities are so used in Germany.

PROCESSES OF MANUFACTURING THE VARIOUS SORTS OF GYPSUM PLASTER USED IN GERMANY.

Germany has no novel methods for mining or quarrying gypsum and transporting it to the mill. In Thuringia and the Hartz the mineral occurs in great hills where no stripping is required.

In the picture, Fig. 34, the hill on the right is composed wholly of gypsum. At various points on the Rhine gypsum is mined. Tramways and endless conveyors carry it in large fragments to

Fig. 84. Mill and one of the quarries of the Krölpa Gypsum Industry, at Krölpa, in Thuringia.

the mill. Here it is treated in various ways, depending on the nature of the product desired.

MANUFACTURE OF GYPSUM PLASTER (STUCK GYPSUM.)

A great deal of gypsum plaster, especially of the finer sorts, is prepared by the same processes which are used in making porcelain plaster. These will be described farther on. In all other processes the gypsum is ground before calcining. Preliminary pulverizing is done in crushers and nippers of the Blake pattern, as in America. For the final fine grinding machines of various sorts are used.

Grinding.—1. As in America, most of the gypsum is ground between burr stone mills. These mills are of two patterns; in one the stones are placed in a horizontal position and in the other they are vertical. The vertical mills are smaller in diameter but

rotate with great speed, are of large capacity and are cheaper than the horizontal mills. They are more generally used than the latter and are regarded by some manufacturers as better fitted for fine grinding. This statement is, however, not undisputed.

Fig. 85. Vertical mills, as installed by the Rhenish Gypsum Industry.
From Prometheus.

2. At Krolpa in Thuringia an American roller mill of the pattern used for flour is employed in one instance, and the owners reported that it gave satisfactory results. In the same mill also a disintegrator of the Stedman type was in use. The latter, however, had been tried by other manufacturers in the Thuringia district and discarded.

CALCINING OF STUCK GYPSUM.

At least three distinct processes, all regarded as successful, must be described under this heading. In addition to these it

will be useful to outline other processes which have been used in Germany, but which have not proven wholly satisfactory. The successful processes are: 1, Calcining in kettles; 2, calcining continuously in rotary kilns of the Mannheim type; 3, calcining in ovens, either individual or continuous.

1. *Calcining in kettles.*—The German calcining kettle consists of a sheet metal cylinder six feet in diameter and three feet high. The bottom is flat and through the cylinder extend no flues as in the American kettle of the same type. This kettle is set in solid masonry directly on a furnace. Usually a battery consisting of three kettles set up together in a series is employed. Firing is generally accomplished by automatic stokers. Each kettle is charged with from one to two tons of gypsum, and, while calcining, the material is agitated by means of a device resembling a steamship propellor, the blades of which extend horizontally across the lower

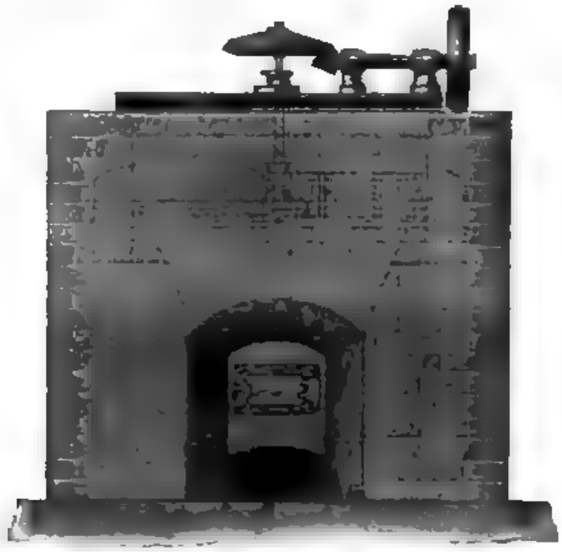


Fig. 83. German calcining kettle, showing agitator
From Prometheus.

part of the kettle. It is rotated by a shaft connected directly by gearing to the line shafting above.

The kettles discharge into a cooling room which is connected by means of automatic carriers with bins located above the sacking rooms, and also with a room in which the dust arising from

the cooling gypsum is allowed to settle. The kettles are also connected with this dust chamber. Through this chamber, therefore, all of the steam given off in the process of calcination is obliged to pass and great quantities of finely divided gypsum, which would ordinarily pass off into the open air with the steam, are caught. The material collected in the dust chamber is removed automatically by means of a spiral conveyor.

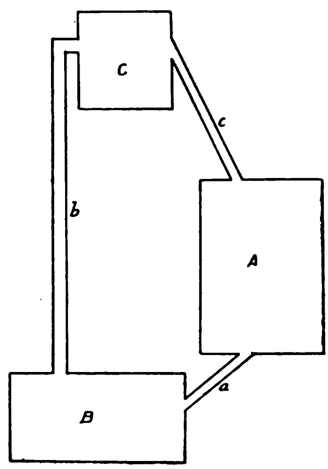


FIG. 37. Sketch showing connections between A. calcining kettle, B. cooling room, and C. dust chamber.

2. *The Mannheim continuous process using rotating cylinders.*—The mill of the Rhenish Gypsum Company, located near Mannheim, is so interesting that it will be well to describe it rather minutely at this point in connection with its unique calcining machinery.

Mannheim is situated on the middle Rhine, fifteen miles northwest of Heidelberg. The works of the Rhenish gypsum industry are located in the village of Wildhof, about four miles north of the city. The plant is modern and fireproof throughout. The roof of the building is made of gypsum boards covered on the outside with asphalt, the inner walls are made of the same material, while the floors are made out of estrick gypsum. In this mill fine grinding of the gypsum is postponed till after calcining. When the material comes from the crushers and nippers it varies in size from the finest powder to fragments as large as an ordi-

nary hickory nut. Varying thus in size, the material goes directly to the calciner.

Fig. 39. Interior of Rhenish Gypsum Industry Mill, showing, to the left, the continuous calciner.

From Prometheus.

The calciner consists of a fire box with an automatic stoker, which is placed in front of and connected with a chamber containing a rotating cylinder. Above this cylinder is a chamber called the forewarmer, through which a spiral conveyor passes, from end to end. A pipe leads from the rotating cylinder to the forewarmer, and connects at the other end with the chimney. Connected with the fire box is a fan by which a forced draft is secured. In the figure this fan, instead of being connected with the fire box, is shown connected with the rotary cylinder. The fire box is heated to a high temperature, and the draft, forced by the fan, passes through the rotating cylinder, and then through the forewarmer. The gypsum is conveyed by bucket elevators from the crushers to a bin above the calciner and thence it flows under the influence of gravity into the forewarmer, through which

it is carried by the spiral conveyor. It then falls directly into the rotary cylinder below. Shelves or buckets on the inside of this cylinder pick up the material and elevate it as the cylinder rotates. When the material nears the top the slant of the shelves is so great that it falls again to the bottom. This process of raising the gypsum and allowing it to fall is constantly repeated, the strong draft of hot air passing through the cylinder from the fire box strikes the gypsum as it falls from top to bottom and moves the fragments toward the rear with a velocity directly proportional to their size. The coarser material moves much more deliberately, and thus is exposed to the heat longer than the finer and more readily calcined particles. In this way, though the material entering the rotating cylinder varies greatly in fineness, the finer is not "dead burned" and the coarser is sufficiently calcined. All of the heat has not been exhausted from the air in passing through the rotary cylinder, and this is for the most part saved by forcing the air, after it leaves the cylinder, through the forewarmer. In this process the heat is so completely utilized that the air and furnace gases pass to the chimney with a temperature of only 80° C. Between the forewarmer and the chimney the dust chamber is situated. Here all of the finer particles are allowed to settle and the air passes on to the chimney practically free from dust. No gypsum was seen about the outside of the mills and the roof showed no trace of dust, while within everything was dust free except the grinding and sacking rooms. To calcine one ton of gypsum by this Mannheim method experience has demonstrated that on the average only [illegible] pounds of rather inferior bituminous coal is required. An automatic recorder indicates constantly the heat of the rotary cylinder, and this with the [illegible] during the entire process of calcining. From the rotary cylinder the gypsum is again elevated to the [illegible] and passes through a spiral conveyor which is surrounded with a water jacket. Here the gypsum is cooled and passes on to the [illegible]. That portion of the gypsum which does not need further grinding is separated by the [illegible] and the rest goes to the [illegible] mills. The process and machinery of the Mannheim mill are to be recommended.

1. For economy of fuel; the amount of coal consumed is only one-half that required for calcining with cylindrical kettles.

2. The continuity of operation greatly reduces the amount of hand labor.

3. The fact that the gypsum is finely ground after calcining results in a great economy of power. The stones of the burr mills also wear much longer and need to be dressed but seldom. The saving due to these facts is considerable.

Before the Mannheim system is introduced, however, it should be determined carefully that the gypsum is as uniformly calcined as by the present American methods. So far as Germany is concerned, it has been demonstrated that the calcining is uniform enough to satisfy the demands made by the German builder. The American mason, however, may require a finer product than the German. A limited amount of soot also settles in the gypsum and it is slightly coated with calcium sulphide, due to the reaction of the sulphur always present in the coal on the gypsum. For ordinary building purposes, however, these do not injure the quality of the gypsum.

3. *Calcining with either individual or continuous ovens.*—This process is used also, and even more commonly, in calcining porcelain gypsum, and will be described later under that heading.

4. *Other devices for calcining that have been tried more or less successfully in Germany.*—Calcining with superheated steam.* A method of calcining by steam called Violett's method from its inventor, is commended by some German technical experts and discouraged by others. The method in Germany is very new, and was not found in operation in any of the mills personally visited. Theoretically all agree that the principle used by Violett is excellent. At the last meeting of the German gypsum association this and similar processes in which superheated steam is used, were discussed, and while all agreed that the quality of the plaster so produced was most excellent, some of those present argued that this excellence was secured at too great an expense of fuel. When gypsum is calcined with superheated steam there is very little danger of "dead burning." A sufficient and uniform temperature may

* Gips und seine Verwendung, von Marco Pedrotti, p. 48. Prometheus Nr. 583.

easily be maintained. The product is not discolored by soot as in the Mannheim process. Cheapness is claimed for it also by Pedrotti.*

Steam at one-half an atmosphere pressure is used and at a temperature of 140° to 150° C. It is generated in an ordinary boiler and superheated in a coil of pipes. The gypsum, unground and in rather large pieces, is stacked in egg shaped ovens which are capable of resisting a moderate amount of pressure from within. Through these ovens the superheated steam circulates. The gypsum is calcined in six hours. By the combination of a number of ovens, which are heated by one boiler plant, certain ovens may be charged while others are being emptied, and the process is made continuous. Pedrotti† and Kruger‡ claim that by this process one ton of gypsum may be calcined at the expense of 110 pounds of bituminous coal. Professor Lechner§ makes the criticism that the apparatus as now in use often gets out of order and for this reason has not been found economical. Other calciners which are practically obsolete are described by Pedrotti.

The calcining of porcelain gypsum.—All agree that the porcelain industry demands a gypsum that has been most uniformly burned and ground. Gypsum which will be readily accepted by the builder will not serve the purpose of the modeler. Tradition, apparently more than anything else, leads certain gypsum calciners to adhere to extremely expensive and ancient methods in calcining porcelain gypsum. Ovens like those employed by the baker in which the gypsum is agitated by long pokers are still used. It is generally admitted, however, that this method is not necessary to produce a plaster of the quality desired. Most of the porcelain gypsum is at present burned in a more inexpensive manner. Much stuck gypsum (gypsum plaster) is also calcined in the same way.

Long rooms with thick walls are constructed out of brick. These rooms have a height of seven feet and are built above a furnace. On the floor of the room and extending out for some distance in front of it is a car track. Cars three feet wide, carry-

* Gips und seine Verwendung
† Ibid p. 50.
‡ Kruger Handbuch der Baustofflehre Band II, p. 29.
§ Prometheus Nr 583.
. Gips und seine Verwendung, pp. 20-50.

ing a rack with five or more shelves quite like the cars used in America in brick driers, are loaded with gypsum and run into the rooms. The gypsum is previously crushed but not ground, the fragments varying in diameter from an inch to one-fourth of an inch. The shelves are loaded and unloaded by hand.

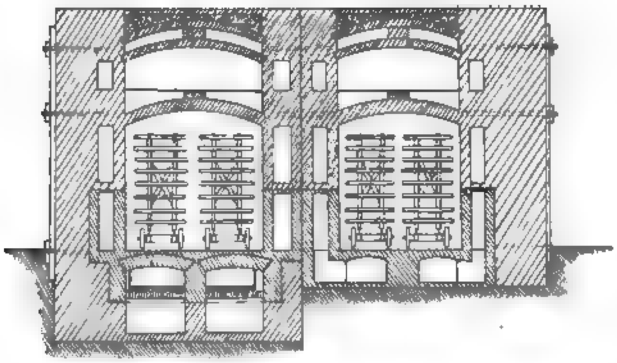


FIG 39 Cross section of kiln for calcining porcelain gypsum and the finest grade of wall plaster The crushed gypsum covers the trays borne by the cars, to a depth of an inch.

The smoke and gas from the furnace do not enter the room containing the gypsum, but pass through the walls in flues. From thirty to thirty-six hours are required for calcining. The room is kept at a uniform temperature of 140° C. and long thermometers inserted through the walls and reading on the outer walls, indicate the heat within at any time. An ordinary oven is emptied three times a week and furnishes each time eight to nine tons of calcined gypsum. An effort is made to change the cars quickly so that the heat of the oven may not be lost. Kruger* claims that a ton of gypsum may be calcined in these ovens with 120 pounds bituminous coal, but this estimate seems entirely too low.

The Bock kiln for the continuous burning of brick is used also in Germany for calcining gypsum.† It consists of a straight chamber 150 to 180 feet long. Through this chamber runs a track on which is placed a series of wrought iron wagons loaded with gypsum. In this tunnel under the track a fire is made which is confined to the center of the chamber, so that the cars freshly loaded are gradually warmed. Those directly above the fire have their load thoroughly calcined and those at the farther end are

* Baustofflehe II, p. 29.
† Gyps und seine Verwendung, pp. 27–31. Baustofflehre I, pp. 214–216.

gradually cooling. The cars are moved by a chain which is drawn by machinery outside of the chamber. They are covered and fit into one another with mortise and tennon so that they form virtually a metal tunnel in the chamber. This prevents exposure to smoke and assures a more even distribution of heat through the contents of the cars.

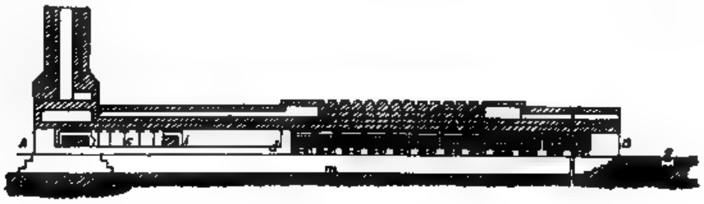


Fig. 40. Section of continuous kiln for calcining the finer gypsum plasters.

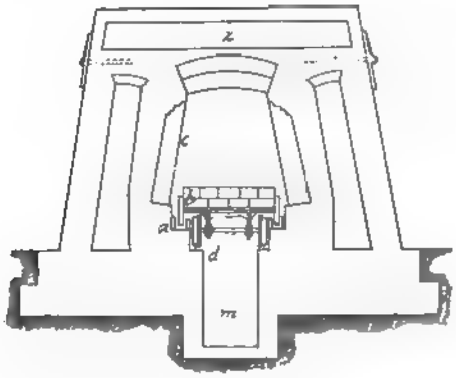


Fig. 41. Cross section of continuous kiln for calcining the finer sorts of gypsum plasters. The fire is at *m* and the cars move slowly along the long tunnel shown in another sketch

ESTRICK GYPSUM KILNS.

Estrick gypsum is calcined in a kiln resembling the ordinary kiln used for burning lime. When possible, the kiln is located near the quarry or mine, and in a hollow or depression, artificial or natural, so that the trucks carrying the rock from the quarry may be run directly to the top of the kiln and there automatically emptied. The kiln will hold about 200 tons at one time, though all of this amount is not subjected to the full furnace heat. The accompanying diagram will best explain its nature. The sketch is made from the side. The fireplace is represented by D, the ashes falling down into E. The gypsum blocks are thrown in at

A, and the whole interior filled. The fireplace on its upper side and rear is grated, and the flames and heat pass directly up

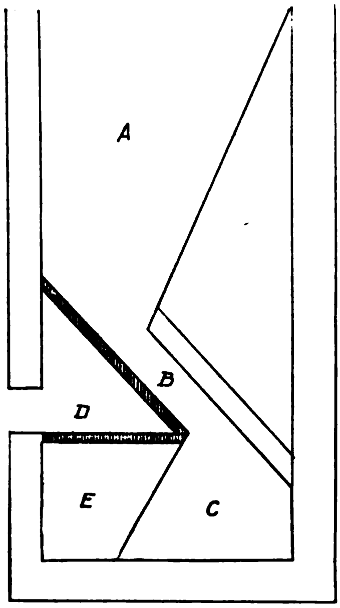


FIG. 42. Sketch of kiln for burning estrick gypsum. (Described in text.)

through A. The hottest part of the kiln is found at B, where a comparatively small amount of gypsum is brought directly in contact with the grates. From time to time the rock which has been exposed to this great heat passes on down into C, the cooling chamber. This will take place whenever the rock already calcined and cooled is removed from C and taken to the mill for grinding. The heat in the lower part of A is so intense that nearly complete combustion takes place, and only gases and hot air, without smoke, pass on up through A, and escape at the top. The process is, then, a continuous one, with but slight loss of heat. There is little danger of overheating the gypsum and no attempt to perfectly control the temperature is made.

Estrick gypsum commands a price twice as great as ordinary gypsum plaster. In every gypsum producing locality the number of estrick kilns is increasing rapidly, and all manufacturers reported a growing demand for this form of gypsum.

TESTS OF GERMAN STUCK GYPSUM.

Samples of stuck gypsum procured in Germany, from the works of Fischer Bros., Krolpa, Thuringia, were tested by Professor Marston at Ames. Stuck gypsum, as previously stated, is made by crushing the raw gypsum to lumps about the size of walnuts and calcining in ovens heated to 300° Fahrenheit for a number of hours, the fine grinding being done after calcining. Stuck gypsum is the only form of plaster of Paris used in the German porcelain factories, and for many purposes in the arts it commands a price double that of kettle calcined plaster. Professor Marston reports as follows:

"Another series of tests was made of German stucco ground very much finer than the Iowa plaster. The fineness of grinding of the different plasters is shown in the table given elsewhere in which it appears that 85 per cent of the German stucco passed a No. 100 sieve as compared with 58.6 per cent to 68.7 per cent of the Flint plaster. More of the Flint plaster was extremely finely ground, however, than the German stucco, as appears from the percentage passing the No. 200 sieve. The tests of the German stucco indicate that it was considerably quicker setting than the Flint plaster, as indicated by the higher strength at the end of one day. There does not appear to be a great difference between the ultimate strength of the German stucco neat and the Flint plaster neat, but with considerable proportions of sand the German stucco gave the higher tests. The peculiar thing about the tests of the German stucco is the lack of adhesion. The result showed very little adhesion for this material."

Two hundred pounds of Iowa gypsum were sent to Germany and burned in "stuck gypsum" ovens, and the plaster so calcined was tested by German porcelain makers and pronounced satisfactory. There is no reason, therefore, why Iowa gypsum should not be used in making stuck gypsum when the American trade demands a plaster with the peculiar properties which this process furnishes.

EXPERIMENTS WITH ESTRICK GYPSUM.

At the suggestion of the writer Professor S. W. Beyer and Mr. I. A. Williams of Ames have undertaken a series of experiments to determine the properties of gypsum calcined at 500° C., the temperature to which German estrick gypsum is heated. The field for estrick gypsum is a large one and it seemed important to prove that gypsum which is commonly regarded as "dead burned"

may have valuable properties. Mr. Williams' letter in which he reports on the preliminary experiments is quoted below:

"Our experiments with the material have of necessity been somewhat long drawn out and we have at present reached a stage only preliminary to the tests which you outlined. This delay is entirely due to the preparatory experiments required to determine the best methods of procedure in burning and mixing the water and the most advantageous conditions for setting and hardening. The results of the work so far have been sufficiently encouraging to demonstrate only the advisability of carrying out a much broader series of tests along these lines. I will outline briefly the work that has been done.

All the gypsum made use of was ground in the raw condition as it comes from the bank, to pass an 80 mesh sieve, .28 millimeters, therefore, being the maximum size of grain. In order to ascertain the best length of time to burn the material, samples sufficient in amount to make about seven standard sized briquettes each were heated in a small muffle kiln. The first sample was drawn when the temperature reached 450° C.; the second after standing in a temperature between 450° and 500° C. for one hour; the third after two hours had elapsed; the fourth after three hours; fifth after four hours; sixth after five hours; seventh, six hours; eighth sample, after seven hours' continuous heating at 450° to 500° C.

These were mixed with water to a consistency such that the mortar would by jarring settle into the molds of itself, shaped in briquette molds and allowed to set by keeping them as damp as possible without disintegration, until they had attained sufficient hardness to resist the effects of water poured directly on them. This preliminary setting required a week and a half to two weeks for those which reached the greatest final strength of the series. After this they were kept well wet, though not saturated, by pouring water on them at irregular intervals. On first drying out, the briquettes shrank to dimensions somewhat smaller than the molds. On setting part of this lost volume was regained by swelling to a slight extent. The use of sand as a dilutent, with the gypsum or of any other inert substance, would decrease these changes in volume.

The burning of gypsum is entirely for the removal of chemically combined water. As this is accomplished in ordinary plaster or stucco at from 100 to 170° C., only a part of the water of hydration is removed, leaving a compound of approximately the formula $(CaSO_4)_2H_2O$ according to Le Chatelier. This compound readily takes up water, becoming set plaster of Paris of the formula of the raw material. When burned to red heat, in the neighborhood of 450° to 500° C., dehydration is complete, or the gypsum is 'dead burned' and the $CaSO_4$ remaining combines with water very slowly to form the hydrate.

In the tests under consideration, the sample drawn when red heat was reached acted exactly like ordinary plaster of Paris, setting quickly almost before it could be gotten into the molds, was pure white in color while the others were of a pinkish cast, and attained the strength and hardness of plaster of Paris. All of the others when first mixed with water showed no tendency to set, working like so much flour. My conclusion regarding No. 1 was, that at 450° C., it had not yet lost all of its water of crystallization; the

others, having stood at substantially this same temperature for different periods had lost this water entirely.

At the end of thirty-nine days, those that had been burned one hour, two hours, three hours and four hours were broken in a Fairbanks' cement briquette testing machine. Following is the summary of results:

One hour burn, 283 pounds per square inch; two hour burn, 290 pounds per square inch; three hour burn, 287 pounds per square inch; four hour burn, 289 pounds per square inch. The variation among the different sets is not great enough to point to any definite length of time, within the four hour limit, as giving better results than any other. Those heated for longer periods than four hours showed very little if any tendency to set under the same treatment as the ones tested. The limits, however, as to length of time and temparature are pretty clearly established as just beginning red heat, when dehydration is first complete, and a continuation of red heat temperatures for four or five hours, under which the gypsum becomes so completely dead burned that it takes up water so very slowly as to preclude the idea of using it in this condition for a mortar material. All that appears to be necessary is complete dehydration and so far as my work has gone, the shorter the burn after this is attained, the more rapidly will it set.

My experiments have not been extensive enough by far to determine very much as to the best methods of manipulation in burning and especially in the treatment of the briquettes while setting and hardening. Some seemed to do better than others treated in exactly the same way." * * * * * * * *

EXPERIMENTS TO SHOW CAUSE FOR THE DETERIORATION OF STUCCO.

Experience has shown and the experiments of Professor Marston, quoted elsewhere, verify the fact that wall plaster when kept for some time under ordinary conditions loses part of its ability to carry sand, while neat plaster although quite old attains an adhesive strength equal to that of fresh plaster. This loss in ability to carry sand is a practical difficulty in the plaster business. Experiments carried out by Professor Weems and Mr. Williams at Ames show that four year old plaster, which had been kept with ordinary care, contained water equal to 8.6 per cent of its weight while water in fresh plaster is limited to 2.2 to 2.6 per cent. To prevent deterioration, therefore, it would seem wise to ship plaster in packages which are as thoroughly protected from the air as possible and to store in rooms that are dry.

nary hickory nut. Varying thus in size, the material goes directly to the calciner.

Fig. 38. Interior of Rhenish Gypsum Industry Mill, showing, to the left, the continuous calciner.
From Prometheus.

The calciner consists of a fire box with an automatic stoker, which is placed in front of and connected with a chamber containing a rotating cylinder. Above this cylinder is a chamber called the forewarmer, through which a spiral conveyor passes, from end to end. A pipe leads from the rotating cylinder to the forewarmer, and connects at the other end with the chimney. Connected with the fire box is a fan by which a forced draft is secured. In the figure this fan, instead of being connected with the fire box, is shown connected with the rotary cylinder. The fire box is heated to a high temperature, and the draft, forced by the fan, passes through the rotating cylinder, and then through the forewarmer. The gypsum is conveyed by bucket elevators from the crushers to a bin above the calciner and thence it flows under the influence of gravity into the forewarmer, through which

it is carried by the spiral conveyor. It then falls directly into the rotary cylinder below. Shelves or buckets on the inside of this cylinder pick up the material and elevate it as the cylinder rotates. When the material nears the top the slant of the shelves is so great that it falls again to the bottom. This process of raising the gypsum and allowing it to fall is constantly repeated, the strong draft of hot air passing through the cylinder from the fire box strikes the gypsum as it falls from top to bottom and moves the fragments toward the rear with a velocity directly proportional to their size. The coarser material moves much more deliberately, and thus is exposed to the heat longer than the finer and more readily calcined particles. In this way, though the material entering the rotating cylinder varies greatly in fineness, the finer is not "dead burned" and the coarser is sufficiently calcined. All of the heat has not been exhausted from the air in passing through the rotary cylinder, and this is for the most part saved by forcing the air, after it leaves the cylinder, through the forewarmer. In this process the heat is so completely utilized that the air and furnace gases pass to the chimney with a temperature of only 80° C. Between the forewarmer and the chimney the dust chamber is situated. Here all of the finer particles are allowed to settle and the air passes on to the chimney practically free from dust. No gypsum was seen about the outside of the mills and the roof showed no trace of dust, while within everything was dust free except the grinding and sacking rooms. To calcine one ton of gypsum by this Mannheim method experience has demonstrated that on the average only 100 pounds of rather inferior bituminous coal is required. An automatic recorder indicates constantly the heat of the rotary cylinder, and this, with the mechanical stoker, insures an even temperature during the entire process of calcining. From the rotary cylinder the gypsum is again elevated to the floor above, and passes through a spiral conveyor which is surrounded with a water jacket. Here the gypsum is cooled, and passes on to the sieves. That portion of the gypsum which does not need further grinding is separated by the sieves and the rest goes to the vertical mills. The process and machinery of the Mannheim mill are to be recommended:

1. For economy of fuel; the amount of coal consumed is only one-half that required for calcining with cylindrical kettles.

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‡ Kruger Handbuch der Baustofflehre Band II, p. 29.
§ Prometheus Nr. 583.
‖ Gips und seine Verwendung, pp. 20-50.

ing a rack with five or more shelves quite like the cars used in America in brick driers, are loaded with gypsum and run into the rooms. The gypsum is previously crushed but not ground, the fragments varying in diameter from an inch to one-fourth of an inch. The shelves are loaded and unloaded by hand.

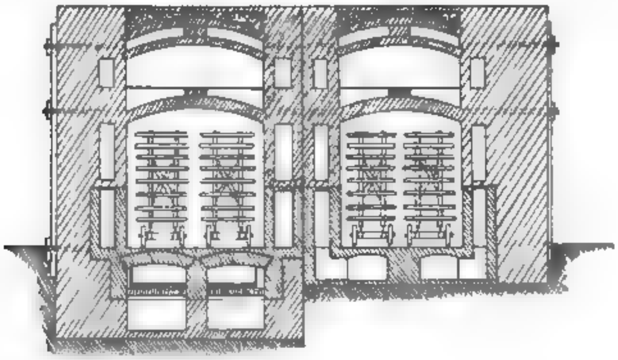


FIG. 39 Cross section of kiln for calcining porcelain gypsum and the finest grade of wall plaster The crushed gypsum covers the trays borne by the cars, to a depth of an inch.

The smoke and gas from the furnace do not enter the room containing the gypsum, but pass through the walls in flues. From thirty to thirty-six hours are required for calcining. The room is kept at a uniform temperature of 140° C. and long thermometers inserted through the walls and reading on the outer walls, indicate the heat within at any time. An ordinary oven is emptied three times a week and furnishes each time eight to nine tons of calcined gypsum. An effort is made to change the cars quickly so that the heat of the oven may not be lost. Kruger* claims that a ton of gypsum may be calcined in these ovens with 120 pounds bituminous coal, but this estimate seems entirely too low.

The Bock kiln for the continuous burning of brick is used also in Germany for calcining gypsum.† It consists of a straight chamber 150 to 180 feet long. Through this chamber runs a track on which is placed a series of wrought iron wagons loaded with gypsum. In this tunnel under the track a fire is made which is confined to the center of the chamber, so that the cars freshly loaded are gradually warmed. Those directly above the fire have their load thoroughly calcined and those at the farther end are

* Baustofflehre II, p. 29.
† Gyps und seine Verwendung, pp. 27-31. Baustofflehre I, pp. 214-216.

gradually cooling. The cars are moved by a chain which is drawn by machinery outside of the chamber. They are covered and fit into one another with mortise and tennon so that they form virtually a metal tunnel in the chamber. This prevents exposure to smoke and assures a more even distribution of heat through the contents of the cars.

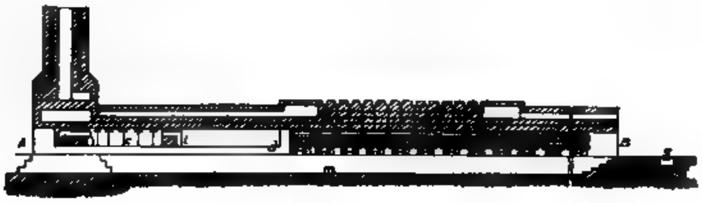


FIG. 40. Section of continuous kiln for calcining the finer gypsum plasters.

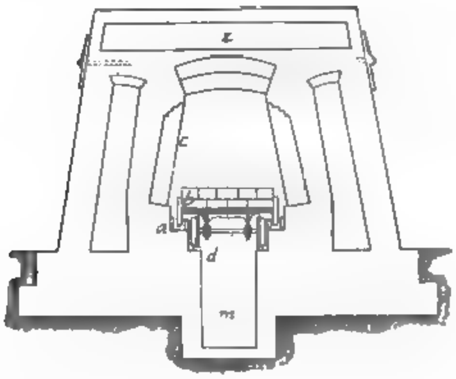


FIG. 41. Cross section of continuous kiln for calcining the finer sorts of gypsum plasters. The fire is at *m* and the cars move slowly along the long tunnel shown in another sketch

ESTRICK GYPSUM KILNS.

Estrick gypsum is calcined in a kiln resembling the ordinary kiln used for burning lime. When possible, the kiln is located near the quarry or mine, and in a hollow or depression, artificial or natural, so that the trucks carrying the rock from the quarry may be run directly to the top of the kiln and there automatically emptied. The kiln will hold about 200 tons at one time, though all of this amount is not subjected to the full furnace heat. The accompanying diagram will best explain its nature. The sketch is made from the side. The fireplace is represented by D, the ashes falling down into E. The gypsum blocks are thrown in at

A, and the whole interior filled. The fireplace on its upper side and rear is grated, and the flames and heat pass directly up

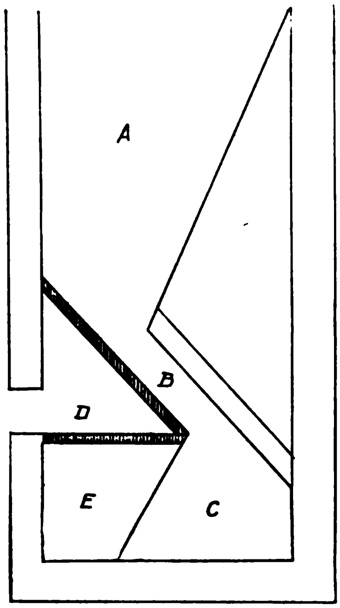


FIG. 42. Sketch of kiln for burning estrick gypsum. (Described in text.)

through A. The hottest part of the kiln is found at B, where a comparatively small amount of gypsum is brought directly in contact with the grates. From time to time the rock which has been exposed to this great heat passes on down into C, the cooling chamber. This will take place whenever the rock already calcined and cooled is removed from C and taken to the mill for grinding. The heat in the lower part of A is so intense that nearly complete combustion takes place, and only gases and hot air, without smoke, pass on up through A, and escape at the top. The process is, then, a continuous one, with but slight loss of heat. There is little danger of overheating the gypsum and no attempt to perfectly control the temperature is made.

Estrick gypsum commands a price twice as great as ordinary gypsum plaster. In every gypsum producing locality the number of estrick kilns is increasing rapidly, and all manufacturers reported a growing demand for this form of gypsum.

TESTS OF GERMAN STUCK GYPSUM.

Samples of stuck gypsum procured in Germany, from the works of Fischer Bros., Krolpa, Thuringia, were tested by Professor Marston at Ames. Stuck gypsum, as previously stated, is made by crushing the raw gypsum to lumps about the size of walnuts and calcining in ovens heated to 300° Fahrenheit for a number of hours, the fine grinding being done after calcining. Stuck gypsum is the only form of plaster of Paris used in the German porcelain factories, and for many purposes in the arts it commands a price double that of kettle calcined plaster. Professor Marston reports as follows:

"Another series of tests was made of German stucco ground very much finer than the Iowa plaster. The fineness of grinding of the different plasters is shown in the table given elsewhere in which it appears that [illegible] per cent of the German stucco passed a No. [illegible] sieve as compared with [illegible] per cent to 68.7 per cent of the Flint plaster. More of the Flint plaster was extremely finely ground, however, than the German stucco as appears from the percentage passing the No. [illegible] sieve. The tests of the German stucco indicate that it was considerably quicker setting than the Flint plaster as indicated by the higher strength at the end of one day. There does not appear to be a great difference between the ultimate strength of the German stucco neat and the Flint plaster neat, but with considerable proportions of sand the German stucco gave the higher tests. The peculiar thing about the tests of the German stucco is the lack of adhesion. The tests showed very little adhesion for this material."

Two hundred pounds of Iowa gypsum were sent to Germany and burned in "stuck gypsum" ovens, and the plaster so calcined was tested by German potters and pronounced satisfactory. There is no reason, therefore, why Iowa gypsum should not be used in making stuck gypsum [illegible] can create demand [illegible] with the [illegible] this present furnishes.

EXPERIMENTS WITH ESTRICK GYPSUM.

At the suggestion of the writer Professor [illegible] and Mr. I. A. Williams of Ames have undertaken a series of experiments to determine the properties of gypsum calcined at [illegible], the temperature at which German estrick gypsum is burned. The [illegible] for estrick gypsum is a large one and it seemed important to prove that gypsum which is commonly regarded as [illegible] [illegible].

may have valuable properties. Mr. Williams' letter in which he reports on the preliminary experiments is quoted below:

"Our experiments with the material have of necessity been somewhat long drawn out and we have at present reached a stage only preliminary to the tests which you outlined. This delay is entirely due to the preparatory experiments required to determine the best methods of procedure in burning and mixing the water and the most advantageous conditions for setting and hardening. The results of the work so far have been sufficiently encouraging to demonstrate only the advisability of carrying out a much broader series of tests along these lines. I will outline briefly the work that has been done.

All the gypsum made use of was ground in the raw condition as it comes from the bank, to pass an 80 mesh sieve, .28 millimeters, therefore, being the maximum size of grain. In order to ascertain the best length of time to burn the material, samples sufficient in amount to make about seven standard sized briquettes each were heated in a small muffle kiln. The first sample was drawn when the temperature reached 450° C.; the second after standing in a temperature between 450° and 500° C. for one hour; the third after two hours had elapsed; the fourth after three hours; fifth after four hours; sixth after five hours; seventh, six hours; eighth sample, after seven hours' continuous heating at 450° to 500° C.

These were mixed with water to a consistency such that the mortar would by jarring settle into the molds of itself, shaped in briquette molds and allowed to set by keeping them as damp as possible without disintegration, until they had attained sufficient hardness to resist the effects of water poured directly on them. This preliminary setting required a week and a half to two weeks for those which reached the greatest final strength of the series. After this they were kept well wet, though not saturated, by pouring water on them at irregular intervals. On first drying out, the briquettes shrank to dimensions somewhat smaller than the molds. On setting part of this lost volume was regained by swelling to a slight extent. The use of sand as a dilutent, with the gypsum or of any other inert substance, would decrease these changes in volume.

The burning of gypsum is entirely for the removal of chemically combined water. As this is accomplished in ordinary plaster or stucco at from 100 to 170° C., only a part of the water of hydration is removed, leaving a compound of approximately the formula $(CaSO_4)_2H_2O$ according to Le Chatelier. This compound readily takes up water, becoming set plaster of Paris of the formula of the raw material. When burned to red heat, in the neighborhood of 450° to 500° C., dehydration is complete, or the gypsum is 'dead burned' and the $CaSO_4$ remaining combines with water very slowly to form the hydrate.

In the tests under consideration, the sample drawn when red heat was reached acted exactly like ordinary plaster of Paris, setting quickly almost before it could be gotten into the molds, was pure white in color while the others were of a pinkish cast, and attained the strength and hardness of plaster of Paris. All of the others when first mixed with water showed no tendency to set, working like so much flour. My conclusion regarding No. 1 was, that at 450° C., it had not yet lost all of its water of crystallization; the

others, having stood at substantially this same temperature for different periods had lost this water entirely.

At the end of thirty-nine days, those that had been burned one hour, two hours, three hours and four hours were broken in a Fairbanks' cement briquette testing machine. Following is the summary of results:

One hour burn, 283 pounds per square inch; two hour burn, 290 pounds per square inch; three hour burn, 287 pounds per square inch; four hour burn, 289 pounds per square inch. The variation among the different sets is not great enough to point to any definite length of time, within the four hour limit, as giving better results than any other. Those heated for longer periods than four hours showed very little if any tendency to set under the same treatment as the ones tested. The limits, however, as to length of time and temparature are pretty clearly established as just beginning red heat, when dehydration is first complete, and a continuation of red heat temperatures for four or five hours, under which the gypsum becomes so completely dead burned that it takes up water so very slowly as to preclude the idea of using it in this condition for a mortar material. All that appears to be necessary is complete dehydration and so far as my work has gone, the shorter the burn after this is attained, the more rapidly will it set.

My experiments have not been extensive enough by far to determine very much as to the best methods of manipulation in burning and especially in the treatment of the briquettes while setting and hardening. Some seemed to do better than others treated in exactly the same way." * * * * * * * *

EXPERIMENTS TO SHOW CAUSE FOR THE DETERIORATION OF STUCCO.

Experience has shown and the experiments of Professor Marston, quoted elsewhere, verify the fact that wall plaster when kept for some time under ordinary conditions loses part of its ability to carry sand, while neat plaster although quite old attains an adhesive strength equal to that of fresh plaster. This loss in ability to carry sand is a practical difficulty in the plaster business. Experiments carried out by Professor Weems and Mr. Williams at Ames show that four year old plaster, which had been kept with ordinary care, contained water equal to 8.6 per cent of its weight while water in fresh plaster is limited to 2.2 to 2.6 per cent. To prevent deterioration, therefore, it would seem wise to ship plaster in packages which are as thoroughly protected from the air as possible and to store in rooms that are dry.

Preliminary Tests of Stucco and Plaster Made by the Civil Engineering Department of Iowa State College.

BY A. MARSTON.

The tests the results of which are given below were undertaken by the Department of Civil Engineering of the Iowa State College in the fall of 1900, as preliminary to a more extensive series of tests to be carried out at a later date. The work was done in co-operation with the Iowa Geological Survey, which obtained the samples and sent them to the department. The gypsum mills at Fort Dodge had previously been visited by the head of the Civil Engineering department. The samples of plaster and stucco obtained were first tested for fineness by sifting them through a series of sieves of varying numbers of meshes per square inch. These are the standard sieves used by the department in mechanical analyses of sand and other similar materials. All of the sieves have been calibrated and the diameters of the largest grains passing the several numbers have been found to be as follows:

Sieve No. 74—0.229 millimeters.
Sieve No. 100—0.115 millimeters.
Sieve No. 200—0.069 millimeters.

The results are given in the table below:

FINENESS TESTS OF PLASTER AND STUCCO.

KIND.	PER CENT PASSING SIEVES.		
	No. 74.	No. 100.	No. 200.
Gypsum from Ft. Dodge Paint Works	99.9	99.7	82.3
Gypsum from Stucco mills, Ft. Dodge, Iowa	68.3	60.0	44.0
Stucco from Ft. Dodge Plaster Company, Ft. Dodge, Iowa	71.9	66.2	49 3
Baker Stucco, Kansas	72.9	58.3	39.5
Kallolite Stucco, Cardiff Gypsum Plaster Co , Ft. Dodge	69.1	63.8	50.2
Baker Plaster, Kansas	68.2	58.7	28.2
Mineral City Wall Plaster, Ft. Dodge	72.1	65.4	49 1
Okarche, Oklahoma Territory, Oklahoma Cement Plaster Co.	77.8	70.2	51.3
Flint Wall Plaster, Iowa Plaster Association, Ft. Dodge.	72.4	64.2	48.1
Acme Wall Plaster, Acme, Texas	74.6	69.2	56.6
Kallolite Wall Plaster, Cardiff Gypsum Plaster Co., Ft. Dodge	70.8	65.5	53.5
Stonewall Plaster, Ft. Dodge Plaster Co., Ft. Dodge	72.4	66.1	54.0
Duncomb Wall Plaster, Duncomb Stucco Co., Ft. Dodge	63.8	57.8	43.6

A preliminary series of tensile tests of the strength of briquettes made of plaster and stucco was then carried out to ascertain the proper percentage of water to use in mixing the materials for the briquettes and to give the experimenter experience in making them. In making the briquettes the water and plaster or stucco were thoroughly mixed by hand and the mortar was then placed in standard cement briquette molds and packed with the finger. The surface of the briquette was smoothed with a trowel. As soon as the briquettes were sufficiently set, which usually took about three hours, the molds were removed; half of the briquettes were then kept in air, and the other half put in water, as shown by the table. At the age of 26 to 28 hours, as shown in the table, the briquettes were broken in a Fairbanks' Cement Testing Machine. The results are given in the following table:

PRELIMINARY TESTS TO DETERMINE THE PROPER PERCENTAGE OF WATER TO USE IN MAKING BRIQUETTES.

Laboratory Number.	KIND.	AGE. In air.	AGE. In water.	AGE. Total.	Per cent sand	Per cent water	Strength lbs. per sq. inch.	REMARKS.
		hrs.	hrs.	hrs.				
1	Kallolite Stucco, from Cardiff Gypsum Plaster Company, Ft. Dodge, Iowa.	3	24	27	0	30	122	
2		27	0	27	0	30	172	
3		3	24	27	0	35	138	
4		27	0	27	0	35	186	
5		3	24	27	0	40	126	
6		27	0	27	0	40	178	
7		3	24	27	0	45	115	
8		27	0	27	0	45	125	
9		3	24	27	0	25	165	
10		27	0	27	0	25	160	
43	Kallolite Plaster, Cardiff Gypsum Plaster Company Ft. Dodge, Iowa.	9	19	28	0	30	210	
44		28	0	28	0	30	217	
45		9	19	28	0	35	227	
46		28	0	28	0	35	204	
47		9	19	28	0	40	172	
48		28	0	28	0	40	193	
49		9	[illegible]	28	0	45	136	
50		28	0	28	0	45	130	

Laboratory Number.	KIND.	AGE In air.	AGE In water.	AGE Total.	Per cent sand.	Per cent water.	Strength lbs. per sq inch	REMARKS.
11	Stucco from Ft. Dodge Stucco Company.	3	23	[illegible]	0	45	113	
12		26	0	26	0	45	104	
13		3	23	26	0	40	182	
14		26	0	26	0	40	196	
15		3	23	26	0	35	191	
16		26	0	[illegible]	0	35	187	
17		3	23	26	0	30	203	
18		26	0	26	0	[illegible]	266	
19		3	23	26	0	25	180	
20		26	0	26	0	25	176	
61	Duncomb Wall Plaster, Duncomb Stucco Company, Ft. Dodge, Iowa.	6	20	26	0	25	......	Dissolved in water.
62		26	0	26	0	25	176	
63		......	......	26	0	30	......	
64		26	0	26	0	30	160	
65		6	20	26	0	35	124	
66		26	0	26	0	35	146	
67		6	20	26	0	40	139	Flaw at center.
68		6	20	26	0	40	135	
69		6	20	26	0	45	149	
70		26	0	26	0	45	101	
91	Stone Wall Plaster, Ft. Dodge Plaster Company.	.....	.....	....	0	25	......	Crumbled in water would not stand weight of clip.
92		...	......	....	0	25	......	
93		9	17	26	0	30	121	
94		26	[illegible]	26	0	30	71	
95		9	17	26	0	35	164	
96		26	0	26	0	35	103	
97		9	17	26	0	40	122	Flaw in briquette.
98		26	0	26	0	40	88	
99		9	19	26	0	45	95	Distorted by water.
100		26	0	26	0	45	160	
		hrs.	hrs.	hrs.				
101	Acme Wall Plaster.	9	17	26	0	25	142	
102		26	0	26	0	25	114	
103		9	17	26	0	30	129	
104		26	0	26	0	30	135	
105		9	17	26	0	35	113	
106		[illegible]	0	26	0	35	116	
107		9	17	26	0	40	83	
108		26	0	26	0	40	91	
109		9	17	26	0	45	80	
110		26	0	26	0	45	77	
111	Flint Wall Plaster, Iowa Wall Plaster Asssociation Ft. Dodge, Iowa.	9	17	26	0	25	202	
112		26	0	[illegible]	0	25	155	
113		9	17	26	0	30	143	
114		26	0	26	0	30	148	
115		9	17	26	0	35	176	
116		26	0	26	0	35	185	
117		......	......	...	0	40	.....	
118		26	0	26	0	[illegible]	187	
119		......	......	....	0	45	......	
120		26	0	26	0	45	113	

Laboratory Number.	KIND.	AGE In air.	AGE In water.	AGE Total.	Per cent sand.	Per cent water.	Strength lbs per sq inch	REMARKS.
71	Mineral City Wall Plaster.	9	17	26	0	25	114	Badly worn.
72		26	......	26	0	25	196	
73		9	17	26	0	30	232	
74		26	.....	26	0	30	232	
75		9	17	26	0	35	168	
76		26	...	26	0	35	144	Slightly
77		9	17	26	0	40	178	cracked.
78		26	.	26	0	40	130	
79		9	17	26	0	45	149	
80		26	...	26	0	45	136	
21	Baker Stucco, Baker Stucco Company, Kansas.	3	23	26	0	45	146	
22		26	0	26	0	45	135	
23		3	23	26	0	40	173	
24		26	0	26	0	40	200	
25		3	23	26	0	35	207	
26		26	0	26	0	35	188	
27		3	23	26	0	30	131	
28		26	0	26	0	30	180	
29		3	23	26	0	25	223	
30		26	0	26	0	25	217	
81	Baker Plaster, Kansas	9	17	26	0	25	......	Dissolved.
82		26	...	26	0	25	53	Cracked.
83		9	17	26	0	30	220	
84		26	......	26	0	30	215	
85		9	17	26	0	35	177	
86		26	......	26	0	35	180	
87		9	17	26	0	40	104	
88		26	......	26	0	40	124	
89		9	17	26	0	45	......	Broken.
90		26	......	26	0	45	95	
51	Oklahoma Cement and Plaster Company.	9	18	27	0	25	118	
52		27	0	27	0	25	86	
53		9	18	27	0	30	120	
54		27	0	27	0	30	114	
55		9	18	27	0	35	69	
56		27	0	27	0	35	111	*Very poor
57		9	18	27	0	40	100	briquette,
58		27	0	27	0	40	104	broken with
59		9	18	27	0	20	49	weight of clip
60		27	0	27	0	20	*	on machine.

The above results show that 30 to 35 per cent of water gave the maximum strength of briquettes. Thirty-five per cent gave a mixture more readily handled in the making of briquettes than 30 per cent, and this percentage was adopted in the remaining tests.

The reason for putting part of the briquettes in water was to ascertain exactly what injurious effect this would have upon them. The results with the short time tests were so favor-

able that it was thought worth while to continue these in the longer time tests.

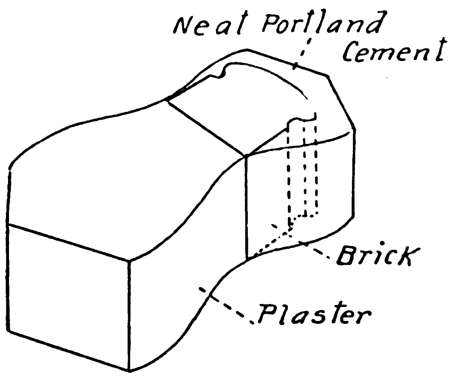
On completion of this preliminary work, fresh supplies of plaster and stucco were obtained and what was intended to be a much more extensive series of tests was planned and begun. It was decided to make both tensile and adhesion tests of the material, and to obtain the strength after the briquettes had been allowed to set for different ages, both in water and in the air. It was also intended to make tests with the neat stucco and plaster as well as with different percentages of sand. This series of tests was only fairly begun, and its completion was prevented by the epidemic of typhoid fever at the college, of which the experimenter was one of the victims, and by some other mishaps. As a result, no tests were made with sand, and only part of the heat tests planned were carried out. The results of this series are given in the table below:

KIND OF MATERIAL.	KIND OF TEST.	KEPT IN.	STRENGTH PER SQUARE INCH AFTER—			
			1 Day.	7 Days.	28 Days	220 Days.
Ft. Dodge Stucco.	Tensile. .	Air......	226	201	329	274
	Tensile. .	Air......	219	210	438	277
	Tensile. .	Water. . .	195	139	187	......
	Tensile. .	Water. . .	208	154	200	......
	Adhesion	Air.	......	87	133	60
	Adhesion	Water ..	......	87	75	......
Kallolite Stucco (Ft. Dodge).	Adhesion	Air......	......	45	115	92
	Adhesion	Water ..	..	31	... ..	.....
Kallolite Plaster (Ft. Dodge product.)	Tensile. .	Air......	219	188	379	288
	Tensile .	Air......	186	230	245	408
	Tensile. .	Water. . .	175	185	168	.....
	Tensile. .	Water. .	189	170	209	......
	Adhesion	Air	.....	52	102	42
	Adhesion	Water ..	... ..	43	....	..
Duncomb Plaster (Ft. Dodge product.)	Tens le .	Air......	211	184	375	335
	Tensile. .	Air......	208	220	360	205
	Tensile .	Water ..	192	172	180	......
	Tensile. .	Water ..	202	175	186	......
	Adhesion	Air......	......	62	81	......
	Adhesion	Water ..	.....	......	81	.. ...

KIND OF MATERIAL.	KIND OF TEST.	KEPT IN.	STRENGTH PER SQUARE INCH AFTER— 1 Day.	7 Days.	28 Days	220 Days.
Mineral City Plaster (Ft. Dodge product.)	Tensile..	Air......	......	190	237	......
	Tensile..	Air	......	301	437	......
	Tensile.	Water...	215	203	195	......
	Tensile..	Water...	192	196	205	......
	Tensile.	Water...	195	.....	......	......
	Tensile..		215	......	......	......
	Adhesion	Air......	......	72	212	......
	Adhesion	Water...	......	......	84	......
Stone Plaster (Ft. Dodge product.)	Tensile..	Air......	131	170	483	386
	Tensile.	Air......	144	228	470	......
	Tensile..	Water...	187	163	182	......
	Tensile.	Water...	214	193	148	......
	Adhesion	Air......	.....	31	80	......
Flint Plaster (Ft. Dodge product.)	Tensile.	Air......	192	224	348	359
	Tensile..	Air......	204	217	285	......
	Tensile..	Water...	188	207	158	.....
	Tensile..	Water...	214	205	163	......
	Adhesion	Air.....	......	64	114	65
	Adhesion	Water ..	......	26	......	.....
Acme Plaster (Texas.)	Tensile..	Air......	107	128	333	193
	Tensile..	Air......	131	175	303	......
	Tensile.	Water ..	82	20	151	.....
	Tensile.	Water...	111	112	154	......
	Adhesion	Air......	......	76	103	47
Baker Stucco (Kansas.)	Tensile.	Air......	227	236	468	405
	Tensile..	Air......	221	208	461	340
	Tensile..	Water...	216	223	154	......
	Tensile..	Water...	226	201	181	......
	Adhesion	Air......	......	.....	117	50
	Adhesion	Water...	...	98	100	.....
Baker Plaster (Kansas.)	Tensile..	Air......	181	195	465	283
	Tensile..	Air......	134	218	286	375
	Tensile.	Water ..	183	196	195	.....
	Tensile..	Water...	185	162	215	......
	Adhesion	Air......	.....	83	105	......
	Adhesion	Water ..	......	55	95	.....
Oklahoma Plaster.	Tensile.	Air......	......	......	......	......
	Adhesion	Air......	......	82	......	62
	Adhesion	Water...	......	63	133	.....

The adhesion tests in the table above were made by taking pieces of No. 2 paving brick from Des Moines and grinding them on an emery wheel so as to make approximately one-inch cubes. Each cube had one face carefully trued to give a cross section exactly one inch square. These pieces of paving brick were

placed in the cement molds with the true surface above referred to exactly at the middle of the mold. The cement or stucco was then placed to fill the remaining half of the mold and the vacant space in which the piece of brick was located was filled with neat Portland cement mortar. The arrangement will be better understood by the following sketch:



Adhesion Test Briquette

FIG. 43.

It was thought that the results of adhesion tests would serve to show whether the tensile strength of the plaster or stucco could properly be taken as a measure of the value for use in plaster. Paving brick was taken as giving the material which could be most readily made standard for such tests. No. 2 paving brick was taken in preference to No. 1 because the No. 1 are so hard burned as to make the preparation of the cubes very expensive. The adhesion surfaces were ground as smooth as could be readily done with an emery wheel.

It will be noticed in the table that as a rule there was a falling off of the strength of the briquettes between the ages of 28 and 220 days. The reason for this is that after the experimenter was taken sick the briquettes were allowed to remain in a basement where they were subjected to contact with very moist air from the condensation of steam from the heating plant. The effect of the moisture in the air shows in the reduction of strength.

Comparison of the strength of the briquettes which were left in water with those left in air indicates that they showed a steady

deterioration. In the end these briquettes partially dissolved so that no tests could be made at the end of the 220 days.

The writer considers that the number of tests made is too small to enable any further conclusions to be drawn. A much more extensive series of tests has now been begun.

Additional experiments carried out since the foregoing were completed are given below and seen to justify the following generalizations:

It appears from the tests that the adhesive strength of plaster is only a fraction of the tensile strength, and that this fraction decreases as the proportion of sand used in the plaster increases. The adhesion tests proved to give much more irregular results than the tensile tests. This is probably due to the greater difficulty of carrying out the tests.

All the tests are still going on. Many more briquettes than have yet been broken were made, and these are being broken from time to time at different ages. It is still too early, therefore, to draw decided conclusions from the tests. The following summary of the results so far obtained is, therefore, to be received cautiously, as later results may modify the conclusions to be drawn.

Two kinds of plaster were tested, the Flint plaster made by the Iowa Plaster Company, Fort Dodge, Iowa, and the Crystal Rock plaster from Blue Rapids, Kansas. The tests do not show any great difference between these two kinds of plaster.

Some of the tests were made on plaster as obtained from the mills, and some on plaster which had been sifted, using only that which would pass a sieve having 100 meshes per lineal inch.

The results do not show any very great difference in the strength of the sifted and the unsifted plaster.

In addition to the main tests of Flint plaster and crystal rock plaster a similar series of tests of Flint plaster four years old was made. The results of these show that the plaster did not deteriorate greatly so far as the strength of the neat stucco is concerned, but it had largely lost its ability to take sand. The tests with sand were very much weaker than the corresponding tests with fresh material. Some of the plaster was sifted through a No. 100 sieve, and it was found that the material which would

pass this sieve was very much stronger than the unsifted material. Either the coarse particles deteriorated more than the fine particles, or perhaps the absorption of moisture from the air caused part of the material to set into coarser grains which were removed by the sifting. The old Flint plaster showed especially poor results in the adhesion tests.

KIND.	PROPORTIONS	STRENGTH				
		1 DAY	1 WK	4 WKS	3 MOS	
Crystal Rock Plaster from Blue Rapids, Kansas; fresh, unsifted Average of 9 tensile tests........ ..	Neat	228	393+	445+	4[illegible]6+	
Average of 6 adhesion tests......	Neat.	50	92	101		
Average of 15 tensile tests.....	1:1	87	320	368	370	
Average of 6 adhesion tests.....	1:1	27	58	48	66+	
Average of 15 tensile tests................	1:2	55	200	212	255	
Average of 6 adhesion tests......	1:2	16	16	21	9	
Average of 15 tensile tests............	1:3	35	148	145	156	
Average of 6 adhesion tests	1:3	......	.....	7		Very weak in spite of great care
Crystal Rock Plaster fresh, sifted Average of 15 tensile tests ..	1:2	57	231	220+	229	
Average of 6 adhesion tests....	1:2	12	27	19	15	

KIND.	PROPORTIONS.	STRENGTH			
		1 DAY	1 WK	4 WKS	3 MOS.
Flint Plaster, made by Iowa Plaster Ass'n. Ft Dodge, Iowa, fresh unsifted. Average of of 15 tensile tests....	Neat.	135	310	402+	
Average of 6 adhesion tests......	Neat	59	92	96	
Average of 15 tensile tests......	1:1	104	308	362+	
Average of 6 adhesion tests......	1:1	33+	93	51+	
Average of 15 tensile tests...........	1:2	64	206	208	
Average of 6 adhesion tests.........	1:2	21+	31—	54—	
Flint Plaster, fresh. sifted. Average of 15 tensile tests	1:2	61—	238+	243	
Average of 6 tensile tests............	1.2	18—	26	22+	
Flint Plaster. fresh unsifted. Average of 15 tensile tests..........	1:3	39	132	139+	
Average of 6 adhesion tests....	1:3	6	10	20	
Flint Plaster, four years old, unsifted. Average of 3 tensile tests.. .	Neat.	155	358	483	

KIND.	PROPORTIONS.	STRENGTH.				
		DAY	1 WK	4 WKS	3 MOS	
Average of 6 adhesion tests......	Neat.	27	*	9		* Broke putting in machine.
Average of 15 tensile tests......	1:2	26+	109	123		
Average of 6 adhesion tests......	1:2	*	*	10		* No adhesion.
Flint Plaster, four years old, sifted. Average of 6 tensile tests.....	1:3	49—	205	256		
Average of 6 adhesion tests......	1:2	7	15—	22		Adhesion poor.
German Stucco. Average of 5 tensile tests......	Neat	300	461	461		
Adhesion tests	Neat	*	*			* No adhesion. Neat stucco too smooth to adhere to the smooth brick.
Average of 15 tensile tests......	1:2	119+	336	3[illegible]6		
Average of 6 adhesion tests	1:2	15	66+	11		ome broke putting in machine.
Average of 5 tensile tests	1:3	75	303	252		
Adhesion tests....	1:3	*	*	*		* Adhesion poor. Broke in spite of great care in handling. Too much sand. Broke putting in machine.

FINENESS TESTS OF PLASTER.

KIND.	PER CENT PASSING.		
	No. 74.	No. 100.	No. 200.
Crystal Rock Plaster	73.7	13.3	2.5
	74 3	55.2	4.3
Flint Plaster, fresh	66.4	58 6	55.7
Flint Plaster, 4 years old	81.9	68.7	52.2
German Stucco	90.5	85.0	19.8

GEOLOGY OF HENRY COUNTY.

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CONTENTS.

INTRODUCTION.

LOCATION AND AREA.

The territory of which Henry county forms a part was purchased from the Sac and Fox Indians through their chief, Black Hawk, in 1832. It was not set off as a separate county until the first session of the Wisconsin Territorial Legislature in 1836, at which time this area was included within the territory of Wisconsin.

Henry county is situated near the extreme southeastern portion of the state. It lies in the second tier of counties west from Illinois and in the second tier north from the state of Missouri. The counties of Louisa and Washington form its northern boundary. On the east the counties of Des Moines and Louisa separate it from the Mississippi river. Lee county stands between it and Missouri on the south, while Van Buren and Jefferson counties touch it on the west.

Its eastern border is but eighteen miles from the Mississippi river, and its southern boundary is about an equal distance from the Iowa and Missouri line. Henry is among the smallest counties in the state. It forms a rectangle twenty-four miles in length, north and south, and eighteen miles in width. It comprises twelve government townships which give it an area of 432 square miles.

Although among the smallest in area, this county is not among the least in attractiveness, either from the standpoint of the agriculturist, or of the geologist, or indeed, of him who appreciates the beauties of landscape expressed in its rich variety of widely stretching prairies, its forest-covered hills and rock-bound streams.

EARLIER GEOLOGICAL WORK.

Among the earliest students of geology in Iowa was Professor D. D. Owen, whose parties worked in the state during the summer of 1849. He refers to some deposits of the Coal Measures in the adjoining counties of Van Buren* and Jefferson† but no

* Owen: Geol. Surv. of Wis., Iowa and Minn., pp. 106-109.
† Ibid, p. 110.

mention is made of any points within the area under consideration.

In 1857 Mr. A. H. Worthen, under the direction of Professor James Hall, made some investigations on the geology of southeastern Iowa. During the progress of this work he visited several points in Henry county and devotes a few pages to the description of its geology.*

Dr. C. A. White, in his report on the Geological Survey of Iowa,† gives a short description of some exposures of the Coal Measures in the southeastern part of the state, but says nothing in regard to deposits of coal occurring within the borders of Henry county.

Mr. Frank Leverett, of the United States Geological Survey, has made extensive observations on the surface features of Henry county. He was the first to note the presence of the Illinoian drift sheet in southeastern Iowa, and to trace its boundary. Among his numerous publications the following contain references which bear upon the geology of the area under discussion: The Deflection of the Big Cedar Creek from its Normal Axis,‡ The Weathered Zone (Sangamon) between the Iowa Loess and the Illinoian Till Sheet,§ the Yarmouth Soil and Weathered Zone and the Illinoian Glacial Lobe.¶

PHYIOGRAPHY.

TOPOGRAPHY.

The surface features of Henry county may be grouped in two distinct topographical areas. The first consists of an undulating prairie, moderately well drained, occupying the northern and northeastern portions of the county. This region belongs, for the most part, to the Kansan drift plain, but the imperfect drainage resulting from its distance from any stream of considerable size and the consequent absence of erosion renders the area wanting in the typical features of Kansan drift topography.

* Hall: Geol. of Iowa, Vol. I, pp. [illegible]-219.
† White: Geol. Surv. of Iowa, 1870, Vol. II, pp. 271-274.
‡ The Aurora, Iowa State Agri'l. College, Nov., 1895.
§ Journal of Geology, Vol. VI, pp. 171 and 172, 1898.
‖ Proc. Iowa Acad. Sci., Vol. V, pp. 71-80, 1898.
¶ Jour. of Geology, Vol. VI, pp. 239-243, 1898.
Monograph 38, U. S. Geol. Surv., pp. 34, 35, 52, 89, 90, 93 and 97.

The level landscape is broken in the northern portion of the county by the presence of two old valleys, one-fourth to three-fourths of a mile in width and fifteen to twenty feet in depth. These depressions are abandoned channels which were eroded in the Kansan drift by temporary streams during some later ice invasion, and whose waters found other channels upon the retreat of the ice. One of these valleys enters the county from the north near the northeastern corner of Scott township. It trends towards the west, passing a short distance north of the town of Winfield. Near this village it divides; one branch bending towards the northwest leaves the county near the northeast corner of Wayne township. It continues westward at some distance north of the county line for ten or twelve miles, when it bends southward and again enters the borders of Henry in the northwest corner of Jefferson township, near the town of Coppock. This channel is occupied in the greater part of its course by the small stream of Crooked creek.

The other branch passes almost directly west from Winfield and forms a conspicuous valley across the northern portion of the county. It unites once more with the former channel near the town of Coppock above mentioned. The Burlington and Western railroad follows this valley for several miles through the central portions of Scott and Wayne townships.

Mr. Frank Leverett has shown that these were channels successively occupied by the Mississippi river when it was pushed over westward by the lobe of the Illinoian ice sheet. This lobe crossed the river from Illinois and covered a narrow portion along the border of southeastern Iowa. A small area in the southwestern part of Henry county, comprising a narrow strip along the eastern edge of New London and Baltimore townships, also owes its topography to this invasion of the Illinoian ice. The rounded ridges and irregular hills which mark the marginal moraine of this drift sheet are prominent for some distance in the township of New London, a short distance east of the town of the same name. Further south, in Baltimore township, the moraine is crossed by the Skunk river. Here it is obscured for the most part by the erosion of that river and its tributaries.

Over all of the remaining southern and southwestern portion of the county, continuing along the western side to the point where

the Skunk river enters, in the extreme northwest corner, the surface presents the erosional features so characteristic of the Kansan drift plain. It is evident that its topography has been impressed upon it by the waters of the Skunk river, the master stream of the county, together with that of its tributaries and their dendritic branches. These streams have intersected the region in all directions. During the slow moving centuries they have cut down their channels entirely through the drift and, in many cases, have carved their beds deep into the underlying limestone. As a consequence we have here a diversified landscape of hill and upland, of valley and prairie. The level plains of varying extent are separated by ravines bordered by rounded slopes, or by wider channels in which the streams flow lazily as they wander from side to side in the broad valleys which they occupy. Occasionally their waters run with heedless haste as they hurry over the stony bottom and past the rocky bluffs which at intervals confine them to a narrower channel. At numerous points along the course of these winding streams the current has been deflected against the side of a bordering bluff and the stream is chiseling wider its valley that already is much too large to be filled by its waters even in their most swollen periods. All of this area is quite perfectly drained by the ultimate branches of Big creek and Big Cedar creek which are the largest streams that pay tribute to the Skunk river within the county.

The general level of the uplands back from the river on either side is determined by the hard, evenly-bedded limestone which occurs near the upper part of the Saint Louis stage. Over the most of this area these hard layers immediately underlie the superficial deposits that cap the hills and cover the level plains. They may be seen exposed in the beds and bluffs of the streams in the townships of Tippecanoe, Center, New London, Salem and Jackson, and doubtless extend over much of the drift-concealed surface of the prairie townships. These compact beds crumble but slowly under the action of the disintegrating agencies of the atmosphere. They stand out at the top of the bold escarpment that overlooks the Skunk river at Oakland Mills. They crown the bluffs that in so many places make beautiful the banks of Big creek. They appear in the crests of the low ledges that outcrop

on either side of the broad valley along the course of Big Cedar creek in the townships of Salem and Tippecanoe. On following back to their source the tributaries of these streams one passes over the same compact layers of white limestone which usually appear in their beds as the uppermost indurated rocks of the county. The influence of these layers upon the topography of the region cannot be overlooked.

Below these compact beds for many feet the rocks are more broken and irregular. Local layers and pockets of soft sandstone and brecciated beds of limestone render the cutting of the streams down to the harder strata which lie near the base of the Saint Louis stage comparatively rapid. For this reason the tops of the hills and the level of the uplands stand thirty to forty-five feet above the beds of the larger streams, whose bordering ledges are almost vertical; the inclined bank of superficial materials sloping back to the general level of the plain above.

The hills here are most of them covered with a thin mantle of loess, but deposits of any considerable depth are very local. Over the greater part of the region the thickness is insufficient to modify the erosional features of the drift. Usually the loess is not so uniformly fine-grained in texture nor so yellow in color as it appears nearer the border of the Iowan drift, or nearer the bluffs of the Mississippi river. In a few places along the Skunk river, however, the westward facing hill slopes have received a deposit of typical loess twenty to thirty feet in thickness. In the cuts that have been made through this material the sides have a tendency to stand almost vertical, the top not sliding downward so early nor to the same extent as it is prone to do in the case of excavations made in the drift.

Besides the work of long continued erosion over this area there are a few points at which it is probable that the wind has also had a share in determining the topography. In the southwestern part of Jefferson township, about one mile east of Merrimac Mills, the level valley on the east side of Skunk river is bordered for some distance by a series of hills of sand instead of the low, talus covered ledges of limestone that usually bound the river at some distance back on either side. These hills vary in height from about twenty-five to thirty-five feet. Some of them are sev-

eral rods in length extending with their long axes east and west, almost at right angles to the river valley. The valley at this point is about one mile in width. Its surface materials are almost pure sand, and it is probable that the hills have been slowly built up by the deposit of materials gathered by the winds as they swept over this level bed of loose sand.

A few miles north of this point, in section 6 of the same township, the regular bank that guards the east side of the river is again replaced by a number of irregular hills. These, however, are composed of the finer loess material instead of sand. At this point the valley of the river is narrower and its surface materials are less sandy than at the place mentioned above, which facts probably account for the difference in the deposits. Both groups of hills are where the prevailing westerly winds sweeping across the valley would lay down their load of dust and debris on coming in contact with vegetation, or on having their velocity checked by the obstructing banks.

Near the central part of section 4, in Salem township, there are a number of interesting mounds which have attracted some local attention. They stand on the east side of the valley of Big Cedar creek, a short distance below what is known as the Bales' ford. The flood plain through which Big Cedar creek flows is at this point about three-quarters of a mile in width. The hills, six in number, stand near together, their tops reaching fifty or sixty feet above the bed of the stream. They are more nearly circular in outline than those in Jefferson township, but their longer axes also extend east and west, nearly at right angles to the valley, where the northwesterly winds would be likely to deposit their load on meeting the opposing banks. On the crest of the hills have been found the graves of some prehistoric men. Popular tradition tells that these hills are tumuli constructed by some primitive people, of sand carried by them from unknown distances, in order that here overlooking the waters their dead might have a beautiful place of burial. Be this story as it may, the hills are composed of rather fine sand of nearly uniform sized grains and so clean that the neighboring farmers often use it for purposes of masonry. They are covered with a forest of oak trees, some

of which are of large size, indicating an age of at least two hundred years.

TABLE OF ELEVATIONS.

The following table taken from aneroid determinations made by Mr. Frank Leverett, and from the table of altitudes of the Chicago, Burlington and Quincy and the Saint Louis, Keokuk and Northwestern railways, gives the height above sea level of some of the principal points in the county. The elevation given by Leverett is that of the channel of the temporary Mississippi river. That taken from the railroad records refers to the level of the top of the ties. It will be noticed that the highest point given in the county is at New London, which is situated on the edge of the Illinoian moraine.

STATION.	Altitude above Sea Level.	Authority.
Winfield	703	Leverett.
Coppock	700	Leverett.
New London	762	C., B. & Q. R. R.
Mt. Pleasant	730	C., B. & Q. R. R.
Ketcham	694½	C., B. & Q. R. R.
Rome	616½ 675	C., B. & Q. R. R. Leverett
Oakland Mills	615	St. L., K. & N. W.
Denova	736	St. L., K. & N. W.
Salem	735	St. L., K. & N. W.
Henry and Lee county line near where it is crossed by St. L., K. & N. W. R. R.	657	Leverett.

DRAINAGE.

It is a fact of common observation that the rivers of southeastern Iowa all flow in a general southeasterly direction towards the Mississippi. Now within the borders of Henry county the streams do not always follow this normal course. Even the larger streams, as the Skunk river and Big Cedar creek, which follow that direction for many miles before reaching the county, here deviate in a very marked degree from the usual southeasterly direction. This peculiar action on the part of the streams points to some exceptional conditions in the history of the county as the cause, and these must be sought within the borders of this interesting region.

The Skunk River.—The present drainage system of Henry county is comparatively simple. The Skunk river embraces the

entire area in its hydrographical basin, and together with its branching tributaries carries away all of the excess of water that falls upon the surface.

This river enters the county in the extreme northwest corner. Digressing from its general southeasterly course, at this point it takes an abrupt bend to the south. With many windings it follows for some miles along the west side of the county, at one time bending to the west of the county limits and again making a turn within its borders. In section 31 of Trenton township it makes a stronger bend to the east for a distance of three miles, returning westward as far as the village of Rome in section 5 of Tippecanoe township, and then resumes its general southeasterly course crossing the townships of Tippecanoe, Center, Jackson and Baltimore, and leaving the county in section 35 of the latter township, about one and one-half miles west from its southeast corner.

In the upper part of its course, above described, the river flows in a valley from three-fourths to one and one-fourth miles in width. This valley on either side is bordered by low bluffs of sandstone and impure limestone, twenty to thirty feet in height. These ledges belong to the middle portion of the Saint Louis stage. The bed of the river is of mud or sand and the stream is not at present cutting its channel deeper. In this part of its course the river is evidently occupying a valley that was eroded before the visit of the Kansan ice sheet. Its bordering banks are comparatively low, and concealed both near the top and the base by drift and debris. Kansan drift may also be found in places within the valley. The above condition would indicate that here the river has appropriated a channel not of its own making, one that was formed by the waters of a preglacial stream. A short distance south of Rome, at the point where the river resumes its more easterly direction, it abandons this old valley. From this place down to the point where it leaves the county the river occupies a newer bed. Along this part of its course the channel is narrower, and the ledges that border it are higher, less covered with waste, and stand more nearly vertical. Near Rome the magnesian beds which belong to the lower portion of the Saint Louis limestone may be seen at the base of the bluffs. Proceeding further downward along its course the river has cut through succes-

sively lower beds. At Webster's mill, a few miles below Oakland, its channel is carved to a depth of twenty-five feet in the strata of the Keokuk limestone. Below this point there is a slight dipping of the layers, and at the old Boylston mill, near the northwest corner of section 25 of Jackson township, the geode shales of the Keokuk sub-stage are exposed in the south bank of the river just above the level of low water.

Seven miles below Boylston mill, and about one mile before leaving the county, the Skunk river receives from the north the waters of Mud creek. At this point deposits of the Keokuk shales stand out in a bluff to a height of twenty feet above the river. Here they are overlain by the thick layers of magnesian limestone which Professor Worthen designated as the Warsaw.

Big Cedar Creek.—Big Cedar creek, the largest tributary of the Skunk river within its area, rises in Harrison township of Mahaska county. It flows in a southeasterly direction for a distance of seventy-five miles, crossing the counties of Wapello, Jefferson and a corner of Van Buren. It enters Henry county near the northwest corner of Salem township. After making a few turns it receives the waters of Little Cedar creek near the northeast corner of section 17, of the same township. Soon after this the stream departs from its general southeasterly course and bends abruptly northward. With many windings it persists in following a northerly direction until it unites with the Skunk river a short distance below Rome. This is only eight miles from the point where the stream makes its northward turn, but in the devious journey its waters have traversed more than double that number of miles.

Throughout the whole of its northerly course Big Cedar creek flows in a wide valley bounded by low ledges, partially drift covered, or by banks of till which belong to the Kansan age. One such bluff composed of clay, containing pebbles and bowlders of various sizes overlooks the stream near the middle of the northwest quarter of section 9, Salem township. At this point the creek bends sharply to the northwest, and its current has been deflected against the bluff that borders the valley exposing a bed of drift for a depth of fifty feet down to the water's edge.

The bed of the stream lies about fifteen feet below the flood

plain which would average over three-fourths of a mile in width, but at no point in its northward journey does its waters cut down to the underlying limestones. Indeed, in many places over the flood plain wells have been put down for a depth of fifty or sixty feet without reaching the indurated rocks.

The above facts testify to a time preceding the invasion of the Kansas ice, in which for a long period the land over this area stood higher than at present. During this time the streams that drained the region cut their channels to a greater depth than they are permitted to do with the present elevation. This interval was followed by the period when the Kansan ice sheet spread its mantle of drift over all of this portion of the state, filling full and completely burying all of these old river channels. After the retreat of the ice a stream of the new drainage system established itself within the banks of the old preglacial valley. After another long period a lobe of the Illinoian ice sheet pushed over for some distance into Iowa from the eastward. This mass of ice crowded the Mississippi river out of its bed and forced it to flow for a time further west. As this temporary Mississippi passed west from Winfield around the margin of the ice, it found the channel which is at present occupied by the Skunk river and appropriated it for some distance, following it southward from Coppock as far as Rome.

Mr. Leverett has also found a wide valley excavated in the Kansan drift and partially filled with till of the Illinoian age, which turns aside from the present Skunk river channel near Augusta* in Des Moines county. This valley, which is over a mile in width, passes south from this point, meeting the Mississippi a few miles farther south than the present bed of the Skunk. Above Augusta this valley is occupied by the waters of the present Skunk river. Along the borders of Lee and Des Moines counties the river flows through a wide flood plain which is much larger than that of Big creek, and probably could not have been formed by the waters of that stream. In the northern portion of Lee county this valley comes up nearly to the level of the neighboring part of the temporary Mississippi. Leverett considers this to be the ancient bed of the Skunk river before the

* Leverett: The Illinoian Glacial Lobe, pp. 121-123.

invasion of the Illinoian ice. If the line of discharge for the Skunk river in pre-Illinoian times was down this channel, the same ice dam which caused the Mississippi to make a turn further westward around its border, would also block the drainage of the Skunk in this direction. During this period the waters of the temporary Mississippi joined with those of the Skunk river at Coppock and passed down the present Skunk river channel as far as Rome. Then owing to the blocked condition of the lower portion of the Skunk, they continued south along the lower course of the present Big Cedar creek to section 17 of Salem township. This lower course of the valley of Big Cedar was probably the line of discharge for the waters of Big and Little Cedar creeks in the pre-Illinoian times the same as at present. It is about one mile in width and is bordered by rather low and partially drift covered ledges of limestone twenty-five to thirty-five feet in height. It has every characteristic of an ancient valley and indicates a much longer period of water action than does the more southern portion of this temporary Mississippi channel known as the Grand Valley.

The presence of the Big Cedar channel probably determined the particular place where the united Skunk and Mississippi rivers should leave the valley of the Skunk. As they continued southward in the Big Cedar creek channel in the direction opposite to that of the waters which it previously carried, they would silt up the bed to a height a little above that of Big Cedar at the point where it enters this channel in Salem township.

When the Illinoian ice melted and the rivers returned to their present course, Big Cedar creek would probably continue to find the southward direction, down this old valley, the line of easiest discharge owing to the slope of the bed determined by the direction of flow of those temporary rivers. The portion of the channel between Rome and section 17 of Salem township would thus for a time have been abandoned. Upon the return of the Skunk river to its present course, a stream would probably at once be formed in the northern portion of this deserted channel, discharging its waters into the river. Finding the task of excavation in this new deposit a comparatively easy one, it soon worked its way backward to the point where Big Cedar entered this valley in Salem

township, diverting the waters of that stream once more northward, in the old direction of flow. Continuing this back erosion a short distance further southward, the bed of Little Cedar creek also would be tapped and the present course of these streams within the county established. The Grand valley would thus be left a deserted channel to tell the partial story of the changes in which it had had a share.

Big Creek.—This is the second largest stream that pays tribute to the Skunk river within the county. It drains the region to the north of the river and belongs distinctively to the central portion of this area. It also enjoys the distinction of being one of the most crooked and winding streams in the state. Big creek has its source in the trenches and small gullies eroded by the water in the eastern part of Canaan township. These smaller branches unite to form a single larger stream near the southeast corner of the township of Marion. From this point the creek winds back and forth across the southern part of Marion township, past abrupt ledges of limestone and beds of softer sandstone. Near the western part of Marion township it receives from the north the waters of Linn and Little Potomac creeks. Soon after this it turns southward and continues in just as zigzag and winding a manner to within less than two miles of the river in section 18 of Cedar township. Here it bends to the southeast and continues its devious course in a general line parallel with the Skunk river, flowing across Center and the northeast corner of Jackson townships, and emptying into the river in section 19 of the township of Baltimore. About two miles before it unites with the river, Big creek receives the waters of Brush creek, whose tributaries drain the greater part of New London township. The headwaters of Big creek are within ten miles of its mouth, and yet this winding stream has a length of more than seventy miles. It forms the principal drainage for the townships of Canaan, Marion, Center, New London, the northeast corner of Jackson and the northwest portion of Baltimore. Along its entire course it is bordered by ledges of sand and limestone. It exposes along its banks the entire thickness of the Saint Louis stage, as that stage is developed in the county, from the shaly fossiliferous layer overlying the white compact beds at the top, to the geode

shales of the Keokuk which underlie the brown magnesian beds at the base.

Big creek is a new stream. It occupies a channel of its own carving since the leveling mantle of the Kansan drift was spread over all of this area. It lies in the region embraced between the moraine of the Illinoian drift on the east and the great bend of the temporary Mississippi river on the north and west. It forms the principal drainage for the east-central portion of the county.

In its westerly course Big creek runs parallel to the old Mississippi valley across the northern portion of the county. After bending southward it continues to flow parallel with the portion of the temporary channel which passes from Coppock to Rome, and finally, after turning to the southeast it still continues parallel with the present course of the Skunk river until by a more abrupt bend its waters meet that stream in the western part of Baltimore township.

Crooked Creek.—Scott township is drained by the numerous branches which form the headwaters of Crooked creek. This stream passes out of the county near the northeast corner of Wayne township. It follows the northward flowing channel of the temporary Mississippi river, and with it returns to the borders of the county in the northwest corner of the township of Jefferson.

Numerous other small streams within this area pay tribute to the Skunk river and to Big creek and Big Cedar creek, but they are not of sufficient size to merit separate mention.

Instead of the normal stream drainage that carries off the surface water over the greater part of the area, at a few points there are developed sink holes. At these places the underlying strata are fissured, or passages have been dissolved in them, through which cracks the water finds its way downward to subterranean waterways. Such sink holes appear in the southwest portion of Tippecanoe township and, again, a few may be seen along Little Cedar creek in the western part of the township of Salem. None of these, however, are more than a few feet in diameter nor are they so numerous as to form an important feature of drainage.

STRATIGRAPHY.

General Relations of Strata.

The ancient geological history of Henry county is written on the rocks which belong to the uppermost system of the Paleozoic group, as that group of rocks is developed in the Mississippi valley. Over all of the southern and southwestern portion of the county the rocks of this system are exposed time after time in the beds and along the banks of the larger streams. In many places a vertical section of thirty to forty feet is laid open to observation. The northern or prairie portion of the area is deeply drift covered and it is but rarely that a stream has carved its channel through the drift to the indurated rocks. Even here the well drill has revealed the fact that the rocks of this same age underlie the till at varying depths.

The glacial series is represented in Henry county by two distinct drift sheets separated by a long interglacial period. These record the changes and vicissitudes of climate to which the region has been subjected in more recent times.

The relations of the different geological formations which are exposed over this area may be represented in the following table:

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	
			[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	
			[illegible]	
		[illegible]	[illegible]	
				[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
				[illegible]
			[illegible]	[illegible]

As will be seen from the above table [illegible]

tem of indurated rocks, and of this system both the upper and the lower series are represented. The two series, however, are separated by an enormous period of time. So long indeed was it after the laying down of the lower, before the rocks of the upper series were deposited, that the surface of the former was dissected and deeply furrowed by the streams which drained the area during its earlier history. At many points the rocks of the upper series can be seen occupying the old channels that were eroded in the lower during this long interval.

Of the lower series there are present the Augusta and the Saint Louis stages, and of the upper the sandstones of the Des Moines. Of the Augusta stage in Henry county there is exposed but the upper part which is known as the Keokuk sub-stage.

Lower Carboniferous or Mississippian Series.

KEOKUK LIMESTONE.

The name Keokuk is applied to this assemblage of strata from the fact that in the bluffs of the Mississippi river at the city of Keokuk these rocks have a greater development and are better exposed than at any other point within the state.

The Keokuk limestone occupies but a limited area in Iowa. It is found only in the counties of Lee, Van Buren, Henry and Des Moines, and rapidly thins out towards the north from the city of Keokuk.

As it is exposed in Henry county the Keokuk limestone presents two distinct phases conveniently designated as the upper and the lower. The lower phase consists of about twenty-five feet of limestone, made up of layers of unequal thickness and of varying degrees of hardness. Very often these layers are interstratified with bands of rather soft bluish colored shale. The beds are fossiliferous throughout their entire thickness.

The upper phase, called the geode shales, consists of a bed of calcareous shale or marl, thirty feet in depth. Within this softer material are imbedded great numbers of siliceous geodes, whose cavities are lined with beautiful crystals of quartz or of carbonate of calcium. This bed contains no fossils. The lower phase, as it appears at Keokuk, has been described by Owen under

the name of the "Lower Archimedes Limestone"* and he refers the geode beds to another series of the Carboniferous. In his report on the Geology of Iowa,† James Hall includes both of these members in the Keokuk limestone, making the geode shales the well marked upper limit for the Keokuk, as does also Dr. C. A. White,‡ who wrote a dozen years after. The later writers on the geology of Iowa have followed the classification of Hall in this regard, and that arrangement will be adhered to in the present work.

Typical Exposures.—Exposures of the rocks of this age are found only in the southern portion of the county. They outcrop in the bed of the streams or appear for a few feet in height along their banks. They form the surface rocks at only a few points, and in such places seem to appear in the anticlines of gentle folds.

One of the best exposures of the lower phase of the Keokuk limestone within the area is seen along a small stream that flows into the Skunk river from the south, a short distance above Webster's mill, in section 4 of Jackson township. On following down the bed of this stream from a spring, about one and a half miles above its mouth, one first passes over layers of brown, magnesian limestone which contain the fossil *Lithostrotion canadense*, Cast. The presence of this fossil marks a definite horizon near the base of the Saint Louis stage wherever in the county these rocks may be exposed. About one-half mile from the spring there is an abrupt change in the character of the rocks. The brown magnesian limestone gives place to light gray crinoidal layers which contain numerous fossils. An exposure in a low bluff at this point shows the following section:

		FEET.	INCHES.
5.	Clay, reddish in color, containing an abundance of gravel	4	
4.	Brown, magnesian limestone, non-fossiliferous	2	
3.	Layer of light gray crinoidal limestone containing the spiral axes of *Archimedes*, *Zaphrentis dalei* and *Spirifer suborbicularis*		8
2.	Thin layer of yellowish, fine-grained limestone which contains large fish teeth		3
1.	Bed of rather soft, bluish gray shale		10

* Owen: Geol. Surv. Wis., Iowa and Minn., pp. 91-96. 1852.
† Hall: Geol. Iowa, Vol. I, pt. 1, pp. 94-96. 1858.
‡ White: Geol. Iowa, Vol. I, pp. 210-212. 1870.

In the above section number 5 is Kansan drift, leached and iron stained. The reddish color is due to the oxidization of its iron from the form of ferrous carbonate or oxide to the ferric condition of the oxide. Number 4 belongs to the lower portion of the Saint Louis stage. It is fine-grained and dolomitic, reacting but slowly with cold hydrochloric acid, and contains no fossils. Number 3 is a gray limestone, containing numerous fragments of crinoid stems, together with the remains of *Archimedes owenanus* Hall, and numerous other Fenestelloid Bryozoans, a large undetermined species of Zaphrentis, besides *Zaphrentis dalei, Spirifer suborbicularis,* and an undetermined form of Spiriferina. This layer belongs to the Keokuk sub-stage and marks the contact between the Saint Louis and the Keokuk limestone at this place. Number 2 is a very narrow layer, weathering to a yellowish color, and containing large teeth belonging to the Selachian type of fishes, among which the following are conspicuous:

Sandalodus lævissimus N. & W.
Deltodus spatulatus N. & W.
Deltodus occidentalis Leidy.

The lower member of the section is a soft shale in which there are but few fossils preserved. Continuing down the stream from this point the following succession of layers is passed over:

		FEET.	INCHES.
12.	Layer of very fossiliferous crinoidal limestone containing Bryozoa, Zaphrentis and Spirifer		4
11.	Layer of soft, bluish gray shale	1	4
10.	Thinly bedded limestone, weathering into thin shaly fragments and containing numerous imperfect fossils	4	2
9.	Bed of shale similar to number 11 above.	1	6
8.	Gray, fossiliferous limestone, coarsely granular		10
7.	Layer of shale resembling numbers 11 and 9 above	2	
6.	Gray, shaly limestone, weathering easily, and crowded with fossils. *Platyceras equilaterale*, *Spirifer keokuk*, *S. tenuicostatus* and *Phillipsia* sp.		11
5.	Shaly beds containing numerous Bryozoans and Brachiopods, a narrow band near the top crowded with small fish teeth	3	

	Feet	Inches
7. Crinoidal limestone in narrow layers which weather into thin fragments, alternating with thin shaly bands. Productus [illegible], Spirifer neglectus, S. [illegible], Derbya [illegible] and Dielasma formosa are abundant throughout this member	[illegible]	[illegible]
6. Layer composed very largely of nodules of chert with limestone filling the interspaces		[illegible]
5. Thin layer of crinoidal limestone containing numerous Productus and Spirifers		[illegible]
4. Alternating layers of shale and [illegible] limestone with few fossils to water's edge	[illegible]	

Number 11 of the above beds contains numerous fossils, conspicuous among which appear fragments of a small Archimedes, *Zaphrentis dalei*, *Spirifer keokuk* of typical form, and *Spiriferina* sp. The shale bands both above and below this member erode very rapidly leaving it standing out prominently in the banks.

Number 6 is crowded with organic remains among which the following are very common. *Zaphrentis [illegible]*, *Z. centralis*, *Glyptopora elegans*, *Actinocrinus [illegible]*, *Camarophoria subtrigona*, *Spirifer tenuicostatus*, *S. keokuk*, *Spiriferina*, sp., *Athyris cf. hirsuta*, *Platyceras equilaterale* and Phillipsia resembling *Phillipsia portlocki*. Near the upper part of the following member, number 5, is a narrow band four inches in thickness which contains great numbers of fish teeth, including species of Orodus, Cladodus, Pœcilodus, Chomatodus, Helodus and Deltodus. The teeth are so thickly crowded in this narrow layer that they give to it a dark, mottled appearance which contrasts strongly with the bluish gray of the preceding and the succeeding beds. Numbers 2, 3 and 4 are all very fossiliferous, containing *Zaphrentis dalei*, *Z. centralis*, an undetermined species of Zaphrentis larger than either of the above, *Derbya keokuk*, *Productus punctatus*, *P. setigerus*, *Productus* sp. *Dielasma turgida*, *D. formosa*, *Spirifer tenuicostatus*, *S. pseudolineatus*, *S. keokuk*, *S. suborbicularis*, *S. neglecta*, *Syringothyris textus*, *Athyris planosulcata* (?) and *Myalina keokuk*.

The assemblage of fossils given above are characteristic of the

Keokuk limestone and indicate that geological horizon at this place.

There is here exposed along the stream and in the bluff a thickness of twenty-seven feet of the lower phase of the Keokuk limestone. The contact of the Saint Louis and the Keokuk is plainly marked and well exposed, but the bed of geode shales which overlies this limestone further south is entirely wanting at this point. The Archimedes bearing phase here succeeds the lower member of the Saint Louis stage without a trace of geode development.

THE GEODE SHALES.

In section 22 of Baltimore township there is exposed in the east bank of Mud creek a bed of geode bearing shales thirty feet in thickness. The shale is calcareous, grayish blue in color and so

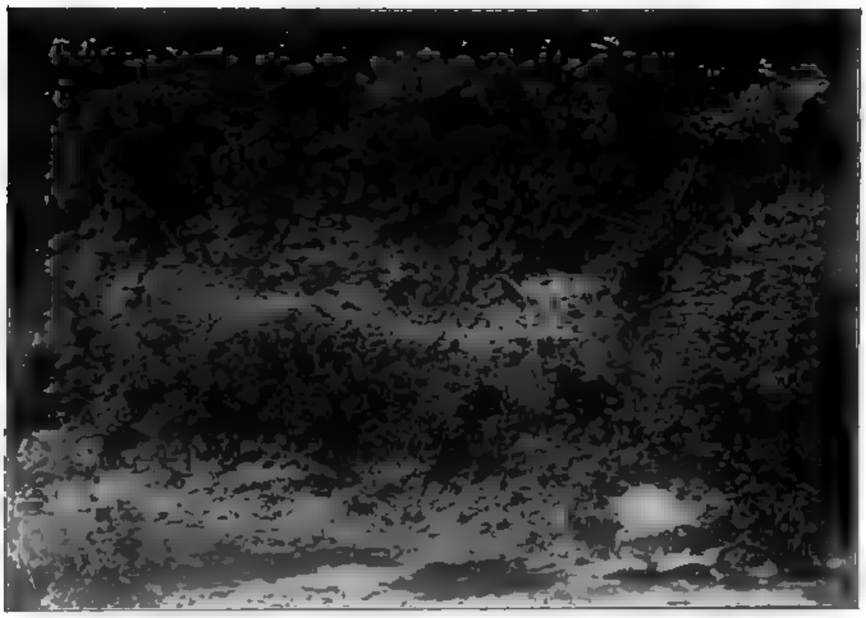

FIG. 44. Exposure of Keokuk limestone on Mud creek, Baltimore township.

soft that it crumbles rapidly on exposure to the weather, thus releasing the numerous rounded or irregularly shaped nodules which it contains. These concretions are usually siliceous and are generally hollow. The cavities are lined with quartz in the

form of bright, transparent crystals, or of waxy white or gray chalcedony, or they are studded with clear colorless crystals of carbonate of calcium. Very often there is found in a cavity, besides the principal mineral which lines it, single crystals of lead or zinc sulphide, or of iron pyrites, or again if the geode is of quartz it may contain a large crystal of calcite. Great quantities of these geodes have weathered out of the bluff and line the bed of the stream from this point to its junction with the Skunk river a mile below. Mud creek has attained not a small degree of local celebrity on account of the number and perfection and the beauty of its geodes. Ornamental mounds of these concretions, their exposed cavities studded with shining crystals, may be seen on the lawns of the lovers of beauty even to the farthest limits of the county.

On passing still further up the creek the harder limestone beds of the lower phase are encountered. Three-quarters of a mile above the geode bluff a low ledge on the west side of the stream rises twelve feet above the water's edge, but it is overlain by no

FIG. [illegible] [illegible] along the bed of Mud creek near [illegible], Iowa. The [illegible] [illegible] at the base of the bluff which shows near the center of the picture.

geode shales, nor do any geodes appear in the bed of the creek between the two points, not at any point further up the stream. The section here exposed shows hard layers of limestone alternating with softer bands of shale, but it was impossible to correlate the different layers with those exposed near Webster's mill with any degree of certainty. Many of the fossils contained in these beds are identical with those of the Webster's mill section, which would indicate that these rocks also belong to the lower phase of the Keokuk limestone, but whether they occur above or below those exposed in Jackson township, or whether they represent a slightly different development of the same beds was not fully determined. The similarity of the fossils in the two exposures would make the latter view seem the more probable. The geode bearing shale outcrops again below this point in the bank of Mud creek at the west end of the wagon bridge which crosses that stream about one mile east of Lowell. At this point the underlying rocks are not exposed but the shales are covered by a bluff of brown, magnesian limestone thirty feet in height. Once more these beds appear a few feet above low water in the south bank of Skunk river near the old Boylston mill, and again they are seen in a bank on the farm owned by Mr. Armour, a few miles east from the latter exposure. These are the only places where the rocks belonging to the Keokuk sub-stage are known to outcrop within the county, and, as may be seen, they are confined to the southern portion. They appear at no definite level, nor are they exposed over any continuous area. The geode bearing phase was probably developed but locally over this region, as the above exposures mark the northern margin of those shales within the state. The rocks of the lower phase of the Keokuk limestone probably owe their appearance near the surface at points widely separated and at different levels, to the gentle folding of the strata over this area. The following is a general section of the rocks of the Keokuk sub-stage as they are developed within the county:

	FEET.
4. Beds of rather soft, calcareous shale becoming harder near the basal portion, containing numerous geodes throughout its entire thickness	30
3. Layers of crinoidal limestone alternating with bands of shale. The harder layers containing teeth of Sandalodus and Deltodus, besides the fossils *Archimedes owenanus*, *Zaphrentis dalei*, and *Spirifer keokuk*..........................	10
2. Beds of soft, fissile limestone interlaid with thicker beds of shale. Near the top of this member is a narrow layer of limestone crowded with teeth of Cladodus, Orodus, Chomatodus and Pœcilodus. Great numbers of the following forms are present throughout the beds. *Spirifer tenuicostatus*, *Athyris*, *Platyceras* and *Phillipsia*	6
1. Layers of hard limestone containing numerous chert nodules near the central portion. Fossils abundant, including *Derbya*, *Productus*, *Dielasma*, *Spirifer*, *Athyris* and *Myalina*	11

The fauna of the Keokuk limestone is of general interest on account of both the number and the variety of its forms. The following list of the more common species will convey some idea of the types which peopled the waters of those old Carboniferous seas.

Palæacis obtusus M. & W.
Zaphrentis varsoviensis Worthen.
Z. centralis E. & H.
Z. dalei E. & H.
Actinotrypa peculiaris Rom.
Glyptopora elegans Prout.
Drymopora sp.
Derbya keokuk Hall.
Productus punctatus Martin.
P. setigerus Hall.
Productus sp.
Camarophoria subtrigona M. & W.
Dielasma turgida Hall.

D. formosa Hall.
Spiriferina sp.
Spirifer logani Hall.
S. keokuk Hall.
S. tenuicostatus Hall.
S. suborbicularis Hall.
S. pseudolineata Hall.
S. neglectus Hall.
Syringothyris textus Hall.
Athyris (Seminula) hirsuta (?) Hall.
Athyris (Seminula) planosulcata (?) Phillips.
Myalina keokuk Worthen.
Phillipsia portlocki (?) M. & W.
Sandalodus lævissimus N. & W.
Orodus ornatissimus N. & W.
Cladodus magnificus Tuomey.
Cladodus sp.
Deltodus spatulatus N. & W.
D. occidentalis (?) Leidy.
Pœcilodus rugosus N. & W.
Chomatodus sp.
Helodus sp.

The Warsaw shales and limestones described by Gordon* in Van Buren county, and by Keyes† in Lee, are entirely absent in Henry. The brown magnesian limestone, which occurs at the base of the Saint Louis stage, immediately overlies the Keokuk wherever the contact between those beds is seen.

THE SAINT LOUIS LIMESTONE.

The rocks of the Saint Louis stage immediately underlie the drift over all of this region, except in the very limited areas, above described, where the rocks of the Keokuk sub-stage appear at the surface, or where the Saint Louis limestone is overlain by the sandstone of the Upper Carboniferous series. The strata of the Saint Louis are composed of limestones, sandstones and shales. They present three distinctly marked phases or divis-

* Iowa Geol. Surv., Vol. IV, p. 213.
† Iowa Geol. Surv., Vol. III, p. 344.

ions which can be readily recognized by their lithological characters wherever these rocks are exposed. The divisions may be referred to as the lower, middle and upper beds.

The first or lower phase consists of magnesian limestones, usually occurring in massive layers. They are rather fine-grained in texture, yellowish brown in color, and dolomitic in character, showing but slight action when treated with cold hydrochloric acid. These beds are characterized by the presence of the coral *Lithostrotion canadense* Cast., in its closely growing, massive form and silicified condition. In some places they contain casts and impressions of other fossils in abundance but these are usually too imperfectly preserved for identification. The thickness of this division varies from over thirty feet in the southeastern corner of the county, near Lowell, to less than fifteen feet further north and west. In the western portion of the county these layers become somewhat sandy in composition but even here the magnesian character still predominates and the yellowish brown appearance is maintained.

This division includes the upper member of the Warsaw limestone as defined by Hall,* and corresponds with the arenaceo-magnesian beds of Gordon in Van Buren† county, and to the Springvale beds of Bain in the counties of Keokuk‡ and Washington.§

The second or middle division is recognized by the extreme variableness of its beds and its generally disturbed condition. It consists of irregular layers of sandstones and shales with an occasional bed of brecciated limestone near the upper portion. It is a record of a time of great disturbance and of rapidly changing conditions. It is for the most part a deposit near the margin of some troubled sea. The presence of local layers which thin out rapidly within a short distance, the pockets of sand and shale, the numerous lenticular beds, and the general irregular appearance of the strata indicate a vigorous wave action. The ripple marks which are beautifully preserved in the sandstone at numerous points, and the local development of oolitic limestone testify to the close proximity of an old shore line. The brecciated phase

* Hall: Geol. of Iowa. Vol. I, pt. 1, p. 97. 1858.
† Iowa Geol. Surv. Vol. IV, p. 215.
‡ Ibid, Vol IV, p. 277.
§ Ibid, Vol. V, p. 148.

D. formosa Hall.
Spiriferina sp.
Spirifer logani Hall.
S. keokuk Hall.
S. tenuicostatus Hall.
S. suborbicularis Hall.
S. pseudolineata Hall.
S. neglectus Hall.
Syringothyris textus Hall.
Athyris (*Seminula*) *hirsuta* (?) Hall.
Athyris (*Seminula*) *planosulcata* (?) Phillips.
Myalina keokuk Worthen.
Phillipsia portlocki (?) M. & W.
Sandalodus lævissimus N. & W.
Orodus ornatissimus N. & W.
Cladodus magnificus Tuomey.
Cladodus sp.
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D. occidentalis (?) Leidy.
Pœcilodus rugosus N. & W.
Chomatodus sp.
Helodus sp.

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† Iowa Geol. Surv. Vol. IV, p. 215.
‡ Ibid, Vol. IV, p. 277.
§ Ibid, Vol. V, p. 148.

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S. keokuk Hall.
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S. pseudolineata Hall.
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Syringothyris textus Hall.
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† Iowa Geol. Surv. Vol. IV, p. 215.
‡ Ibid, Vol. IV, p. 277.
§ Ibid, Vol. V, p. 148.

is usually represented by a bed of shattered limestone of variable

FIG. 46. Irregular beds of the Verdi division of the Saint Louis limestone, near Cakland Mills, Iowa.

thickness. It occurs only near the upper portion of the division and is usually associated with nodules of chert. The brecciated character is not so pronounced over this area as it is in the neighboring counties of Van Buren and Lee. It seldom attains any great thickness and at some points it is altogether wanting. Throughout much the greater portion this division consists of sandstones interstratified with an occasional bed of shale or a thin stratum of limestone. The latter is often oolitic in character. Near the central portion there occurs a band of flint, twelve to twenty inches in thickness, which is persistent over wide areas at this horizon, and forms one of the distinguishing features of the division.

The entire thickness of the deposits which constitute the middle phase of the Saint Louis limestone would average about thirty feet, but at a few localities they reach a depth of fifty, and are throughout almost wholly barren of organic remains. This division immediately overlies the magnesian beds above described

and is followed by the regular layers of white, compact limestone. It corresponds with the arenaceous portion referred to by White* in discussing the Saint Louis limestone. It is the equivalent of the Brecciated Limestone of Gordon† and Keyes‡ and of the Verdi beds of Bain§ in the present series of the Iowa Geological Survey reports.

The upper division of the Saint Louis stage records a more stable condition of this portion of the earth's crust during the period of its deposition. Its rock materials were laid down in deeper waters and in the lower portion consist of uniformly bedded, light gray limestones, very compact, and containing numerous fossils in the shaly bands between the layers. These beds grade upward into a softer, somewhat shaly deposit which weathers rapidly, and contains an abundance of fossils in a good state of preservation. The strata of this division have been thrown into gentle folds, but the disturbance was not sufficient to cause more than a slight flexure of the beds. This phase, as developed in Henry county, reaches a maximum thickness of twenty feet. It is distinguished by the compact, light colored limestones arranged in regular layers and containing the fossils *Rhynchonella* (*Pugnax*)*ottumwa*, *Dielasma turgida*, *Spirifer keokuk* and *Allorisma marionensis*. It corresponds with the gray flag-like limestone referred to by Keyes in the Des Moines county report, and with the compact and granular limestone of Gordon in Van Buren, and with the Pella beds of Bain in the counties of Keokuk and Washington described in the reports above cited. Inasmuch as Mr. Bain has consistently applied names to these three divisions as they appear in the neighboring counties of Keokuk and Washington where the rocks of this stage attained a development somewhat similar to that reached in Henry county, it is thought best for the sake of uniformity in nomenclature to adhere to the names proposed by him for these divisions. In accordance with this plan the lower, middle and upper phases of the rocks of the Saint Louis stage will be designated as the Springvale, Verdi and Pella beds respectively.

The Springvale division takes its name from Springvale mills,

* White: Geol. Surv. of Iowa, Vol. I, p. 216. 1870.
† Gordon: Iowa Geol. Surv., Vol. IV, p. 216
‡ Keyes: Iowa Geol. Surv., Vol. III, pp. 348-349.
§ Bain: Iowa Geol. Surv., Vol. IV, p. 279 and Vol. V, pp. 149-150.

in the western part of Keokuk county, where the rocks of this phase are well developed. The Verdi quarries, from which the name of the middle division was taken, are found in the southern part of Washington county. The Pella beds owe their name to the fact that rocks of this phase are well exposed near the town of Pella, in Marion county.

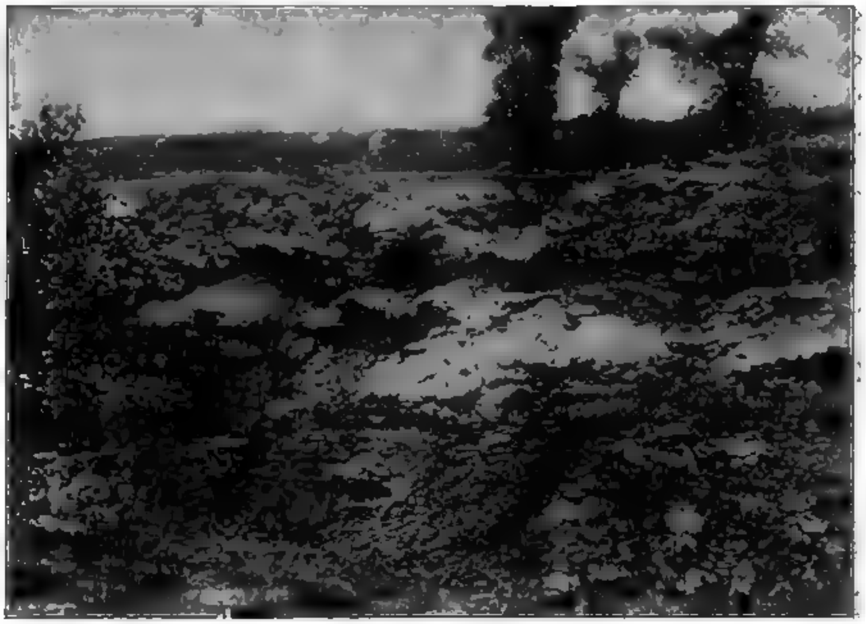

FIG. 47. Exposure of the middle portion of the Saint Louis limestone, at the old Winter's quarry near Mt. Pleasant, Iowa.

The characteristics of the rocks of the Saint Louis stage as a whole, together with those which distinguish each of the divisions, will be best understood by the consideration of the following exposures.

The old Winter's quarry, which is located in the south bank of a small stream emptying into Big creek from the north, near the railroad bridge in the Se. 1/4 of section 17, Center township, shows the following section:

	FEET.
12. Reddish brown clay, containing gravel and small bowlders	4
11. Soft, shaly limestone of gray color, weathering into thin fragments and containing numerous remains of *Productus marginocinctus*, *Rhynchonella ottumwa*. *Dielasma turgida*, *Spirifer keokuk*, *Athyris subquadrata* and *Allorisma marionensis*	6
10. Fine-grained, compact limestone of light gray color, layers ten to twenty inches in thickness, containing *Productus tenuicostus*	5
9. Evenly bedded, gray limestone in layers two to eight inches in thickness containing the fossils *Rhynchonella ottumwa*, *Dielasma turgida* and *Spirifer keokuk*	6
8. Narrow layers of light gray flag-stones, two to four inches in thickness. Fossils similar to number 9 above	1
7. Undulating layers of fine-grained limestone, one to three feet in thickness, containing but few fossils	8
6. Fine-grained, brecciated, gray limestone, non-fossiliferous, in places much shattered	5
5. Layer consisting of lentils and irregular beds of sandstones and shales	6
4. Beds of light colored, arenaceous limestones in places flexed and often brecciated	6
3. Layer of flint in the form of a band rather than that of nodules	1½
2. Impure limestone, yellowish in color, the upper portion in thin layers, the lower a single bed three feet in thickness	4
1. Laminated beds, one to three inches in thickness, consisting of brown, magnesian layers above, thin layers of oölitic limestone in the central portion and arenaceo-magnesian limestone below	5

In the above section number 1 contains numerous silicified corralla of the fossil *Lithostrotion canadense* in the closely growing form. The upper surface of this member is here exposed over an area of several square rods. It presents numerous rounded elevations two to four feet in height and ten to twenty feet in diameter.

These elevations appear as if some force from below had pushed the strata vertically upward at those points. Many of the layers, both of numbers 1 and 2, show beautiful ripple marks which are exposed over an area several square feet in extent. This ripple marked sandstone as well as the bands of oolite which appear in the first member plainly tell us that this was the site of an ancient beach at the time these rock materials were laid down. Number 3 is a layer of almost pure flint. A few rods west of this place, across the railroad track, there is exposed in corresponding beds a second band of chert, two feet in thickness, about four feet above the first. It is not surprising that the fossil *Lithostrotion canadense* always occurs in a silicified condition when the rocks of this horizon contained silica in such quantities as to make possible the deposit of these bands so closely overlying the beds in which that coral is found. The heavy layers of numbers 1 and 2 in the above section, composed of magnesian and arenaceo-magnesian limestone, and containing the fossil Lithostrotion as here found, represent the

FIG. 48. Exposure of limestone in Parkins' quarry, showing the even layers of the Pella sub-stage.

Springvale beds. The broken and irregular layers of sandstones and shales together with the brecciated or oolitic beds of limestone, embracing numbers 3 to 7 inclusive, belong to the Verdi phase; while numbers 8, 9, 10 and 11, consisting of hard, fine-grained, evenly bedded limestone and containing numerous fos-

sils, as given above, constitute the Pella beds as they are developed within the county.

In a quarry belonging to Mr. Levi Parkins, on the south bank of Little Cedar creek, near the southwest corner of section 22, Salem township, the following succession of layers may be seen:

		FEET.
6.	Reddish colored clay, in the lower portion containing gravel and small bowlders...	4
5.	White, compact, fine-grained limestone, in layers eight to twelve inches in thickness, and containing the fossils, *Rhynchonella ottumwa*, *Dielasma turgida*, *Spirifer keokuk* and *Allorisma marionensis*........	3
4.	Fine-grained limestone similar to number 5, layers three to seven inches in thickness and separated one from another by a clayey seam of one-half to one and one-half inches. These seams contain many fossils similar to number 5.........	4
3.	Irregular layers of yellowish colored impure limestone, one and one-half to two and one-half feet in thickness, non-fossiliferous and containing numerous nodules of chert	6
2.	Layers of oolitic limestone, the grains of rather large size	½
1.	Arenaceous limestone in layers varying from two or three inches to one foot in thickness, exposed to the water's edge...	2½

In the above section number 6 is the reddish colored, oxidized clay of Kansan drift. The upper portion to the depth of about one foot is of fine-grained material and contains no gravel. It has probably been deposited in part by the wind, and again a part of it may have been slowly pushed downward from the higher land by the slow action of the rain. Numbers 4 and 5 consist of fine-grained, compact layers of light colored limestone. The beds are similar in character throughout, and represent a period of continuous deposition under uniformly quiet conditions. In the upper member the layers have a somewhat greater thickness than in the lower and with less conspicuous shaly partings between them. These two members present the distinctive characters of the Pella beds both with respect to their lithological

characters and the fossils which they contain. They yield the following species in abundance: *Zaphrentis pellaensis, Productus marginocinctus, P. tenuicostus, P. ovatus, Rhynchonella (Pugnax) ottumwa, Dielasma turgida, Spirifer keokuk* and *Allorisma marionensis*. The first four of the above list are limited to the upper member, while the rest persist throughout the layers of both. These two members correspond to numbers 8, 9 and the lower part of 10 of the Winter's quarry exposure.

Numbers 1, 2 and 3 in the above section contain but few fossils. They represent the Verdi beds, but at this point the development is somewhat different from that of the corresponding phase at Winter's quarry, on Big creek. So changeable, indeed, were the conditions during the deposition of the materials of the Verdi division that at no two points separated by even one mile is there found the same succession of layers. Number 3 contains numerous nodules of chert, varying in size from a few inches to two or three feet in diameter. These nodules are imbedded in a rather fine-grained, impure limestone. Layer number 2 is a narrow band of oolite. The development of oolitic limestone is not uncommon in this division of the rocks of the Saint Louis stage. Very often it occurs in layers much thicker than that of number 2 above. The sandstone of number 1 is here exposed at the surface near the level of the water, and presents beautiful ripple marks which may be traced continuously for a distance of seventy-five feet.

About three miles southeast of the Parkins' quarry, in section 35 of Salem township, the following layers outcrop in the south bank of Little Cedar creek near the Henry and Lee county line:

		FEET.
3.	Reddish brown clay, containing gravel....	6
2.	Two layers of fine-grained, yellowish gray limestone, each about sixteen inches in thickness and containing numerous forms of Bryozoa, *Productus tenuicostus*, *P. ovatus*, *Rhynchonella ottumwa*, *Dielasma turgida* and *Spirifer keokuk*.........	2 2/3
1.	Layers of light gray limestone, three to eight inches in thickness, containing numerous individuals of *Rhynchonella ottumwa*, *Dielasma turgida*, *Spirifer keokuk* and *Allorisma marionensis*.......	5

In the above section number 2 corresponds with the lower por-

tion of number 10 of the Winter's quarry section, and it immediately overlies number 5, of Parkins' quarry. Number 3 corresponds with number 9 of the Winter's quarry beds, and with the upper five feet of the Parkins' quarry exposure.

In the Nw. ¼ of section 20, of Jackson township, on the farm owned by Mr. Ed. Masden, there is exposed in a ravine the following layers:

	FEET.
3. Gray, shaly beds, very fossiliferous, containing in abundance *Zaphrentis pallaensis*, *Rhynchonella ottumwa*, *Dielasma turgida*, *Spirifer keokuk* and *Athyris subquadrata*	2
2. Thicker, fine-grained layers, harder than the above and containing fewer fossils..	3
1. Evenly bedded layers of light gray limestone, the seams between the layers crowded with the fossils *Rhynchonella ottumwa*, *Dielasma turgida*, *Spirifer keokuk* and *Allorisma marionensis*	5

The above layers also represent the upper portion of the Pella beds. Number 3 corresponds with the lower part of number 11

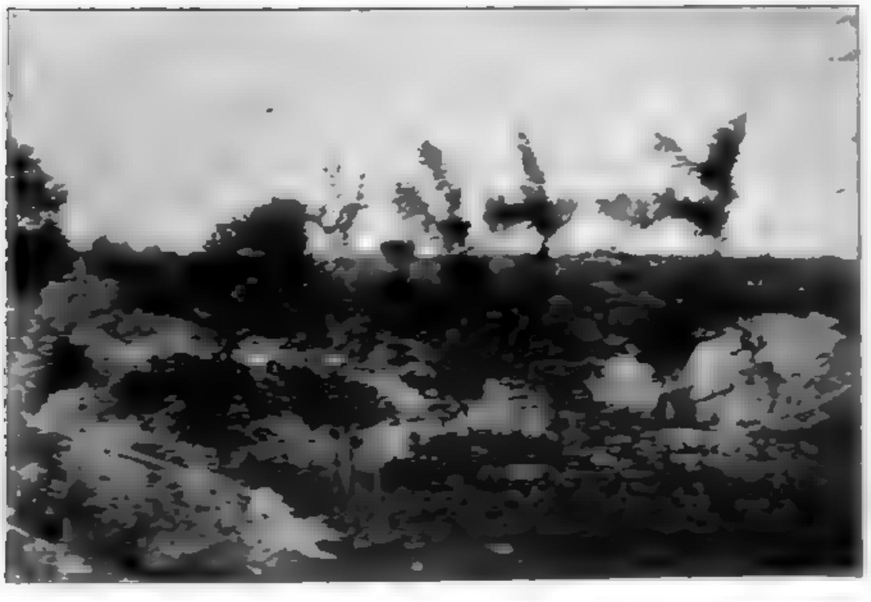

FIG. [illegible] View showing the slightly folded layers of the upper beds of Saint Louis limestone [illegible] township.

of the Winter's quarry section. Number 2 is the equivalent of number 10 in the same exposure and of number 2 of the section near the Henry and Lee county line. Number 1 corresponds with number 1 of the latter section, with the upper portion of the Parkins' quarry section, and with number 9 of the beds at Winter's quarry. At this place the layers, which in the other exposures above cited, have a horizontal position, are inclined at an angle of nearly 45°. The exposure is in the arch of a fold, the beds sloping off in two directions.

In the eastern part of section 6, Baltimore township, there is exposed in the banks of Brush creek, just north of the wagon road and west of the bridge, the following succession of layers:

		FEET.	INCHES.
9.	Clay, containing gravel and small bowlders	6	
8.	Bands of shale alternating with narrow layers of limestone; the entire series weathering rapidly and containing numerous fossils, among which the following are conspicuous: *Zaphrentis pellaensis*, *Productus marginocinctus*, *Rhynchonella ottumwa*, *Dielasma*, *turgida*, *Spirifer keokuk*, *Athyris subquadrata*, and *Allorisma marionensis*	4	
7.	Layers of fine-grained, evenly bedded, white limestone, varying in thickness from two to twelve inches, the shaly partings between the layers one to two inches in thickness and crowded with fossils	9	
6.	Layer of very compact, fine-grained limestone		10
5.	Flagstone layer of fine-grained, light gray limestone		6
4.	Narrow flagstone layer		3
3.	Hard, fine-grained, bluish colored limestone		4
2.	Bed of soft sandstone, presenting numerous beautiful examples of cross bedding	12	
1.	A bluff of disturbed beds of sandstones and shales, much broken and very irregular, exposed about one and one-half miles further down the creek..................	45	

In the above section numbers 1 and 2 represent the Verdi beds in their characteristic disturbed and shattered condition, and

yield no fossils. Number 1 consists, for the most part, of sandstones interbedded with lentils and pockets of shale, and occasional masses of brecciated limestone. In the lower portion were found small deposits of impure coal or carbonaceous material two to four feet in length and one to two inches in thickness. The layers at this point are too changeable and discontinuous to be correlated with those of any known exposures of the Verdi beds. Number 2 is a more uniform deposit than the preceding, but is only a local development. Numbers 3 to 8 inclusive embrace all of the members of the Pella beds in their normal condition. At this place also these layers are slightly flexed, as may be seen in the accompanying photograph, but the strata are not inclined at so great an angle as they are in the exposure on the farm of Mr. Masden, in Jackson township.

In the east bank of the Skunk river, about one mile above the old Millspaugh mill, in section 30 of Trenton township, the following succession of layers may be seen:

	FEET.	INCHES.
7. Bed of fine-grained impure limestone, somewhat brecciated and carrying no fossils	3	
6. Bed of brownish colored shale	3	
5. Layer made up of flint nodules, their interstices filled with limestone		3
4. Layer of arenaceous limestone which often resembles oolite		10
3. Layer of variable sandstone in places hard and coarsely granular and again within a short distance it may be soft and fine-grained	2	4
2. Bed of arenaceous limestone with grains of sand one-fourth of an inch in diameter, among which are imbedded several small fragments of chert	1	
1. Beds of dark gray, coarsely granular limestone in layers four to sixteen inches in thickness, containing numerous fragments of crinoid remains, and other fossils in an imperfect condition, among which forms of Bryozoa, a species of Dielasma, and Spirifer are abundant	4	

Sections similar to the above might be multiplied in every ravine over this portion of the county. The exposure represents

the rocks of the lower part of the Verdi division, and the members are the equivalent of numbers 2 to 5 inclusive of Winter's quarry.

Near the central part of section 6, Center township, a very instructive section is exposed on the east bank of Big creek. This may be called the Center township exposure, and shows the following beds:

		FEET.	INCHES.
9.	Yellowish brown clay containing gravels..	2	
8.	Bed of light gray, fine-grained, non-fossiliferous limestone in layers eight to sixteen inches in thickness	3	6
7.	Narrow band of clayey marl crowded with the casts of a fossil which somewhat resembles a species of Athyris		4
6.	Layer of hard gray limestone without fossils	2	6
5.	Bed of light colored sandstone, rather loose and incoherent throughout	8	
4.	Layer of granular limestone, light gray in color, and containing no fossils..........	1	8
3.	Bed of fine-grained, yellowish brown, magnesian limestone, in layers four to sixteen inches in thickness; non-fossiliferous	10	
2.	Bed of light gray, brecciated limestone, mostly fine-grained and in places much shattered and broken	15	
1.	Bed of brown, impure limestone in layers eight to twenty inches in thickness, containing silicified coralla of *Lithostrotion canadense*	4	

In the above exposure number 1 represents the upper portion of the Springvale division of the Saint Louis stage.

Mr. Bain says* that in Washington county the shaly character of the Springvale beds becomes the more prominent, and the diagnostic fossil, *Lithostrotion canadense,* is rarely found, while to the west the division is more generally represented by brown, earthy limestones. As will appear in the sections of the Saint Louis limestone in Henry county, the Springvale division consists of brown, magnesian limestone which becomes somewhat arenaceous in places, but at no point, except at the isolated exposure

* Bain: Iowa Geol. Surv., Vol. V, p. 148.

near Winfield, does the shaly character above mentioned become conspicuous. The deevlopment of the rocks of this phase is similar to that found in Van Buren county by Mr. Gorden*, and the horizon is always distinguished by the presence of the fossil *Lithostrotion canadense,* which usually occurs in its massive form and silicified condition.

Numbers 2 to 8 inclusive belong to the Verdi beds. The successive layers are much more regular at this point than they are in the exposure of the corresponding phase in Baltimore township. The former beds also contain a much larger proportion of limestone.

Number 7 of the above section is continuous over the entire northeastern portion of the county and furnishes a valuable means of correlating the layers of this division in exposures so widely separated that the arrangement and the degree of disturbance and the lithological characters of the rocks present a very different appearance.

In the northern part of section 3 of Jefferson township, near the Henry and Washington county line, there are exposed the following layers which may be designated as the Jefferson township section:

	FEET.	INCHES.
7. Clay containing gravel and small bowlders	4	
6. Layers of light gray limestone, two to four inches in thickness, checked with numerous water passages and containing no fossils	3	
5. Bed of fine-grained sandstone, light gray in color, in places loose and incoherent..	1	4
4. Layers of light gray limestone ten to fifteen inches in thickness, without fossils, and containing numerous nodules of chert	5	
3. Band of clayey marl crowded thickly with the casts of a fossil which somewhat resembles a species of Athyris		4
2. Bed of gray, fine-grained limestone, somewhat brecciated and containing no fossils	3	
1. Bed of soft, light colored, fine-grained sandstone, exposed to the water's edge..	1	

About ten rods from this exposure, in the bank of the same

* Gordon: Iowa Geol. Surv., Vol. IV., p. 215.

stream, the following layers outcrop in such a position as to indicate that they immediately overlie number 7 of the above section, but they do not appear in any other known exposure within the area.

	FEET.
3. Bed of shattered, light gray limestone, containing no fossils	3
2. Loose, fine-grained, light colored sandstone	4
1. Brown arenaceo-magnesian limestone, containing no fossils	4

About two miles west of Wayland, in Jefferson township, the following layers appear in the bank of a small stream:

	FEET.	INCHES.
6. Bed of brown sandstone, rather hard and coarsely granular	4	
5. Layer of white, fine-grained, non-fossiliferous limestone	1	2
4. Soft, fine-grained sandstone	12	
3. Layers of light colored limestone, eight to ten inches in thickness, containing no fossils	1	6
2. Band of clay or marl containing very numerous casts of a fossil which somewhat resembles a species of Athyris		4
1. Layers of light gray, non-fossiliferous limestone down to the level of the stream	2	

In the latter section, number 1 corresponds with number 2 of the Jefferson township section, and with number 6 of the Center township exposure. The narrow band of clay, number 2, is crowded with the remains of a small brachiopod. The shells became filled by infiltration of calcite and later the shell substance was removed, so there is left only the casts, which are in such a crystallized condition as to render the determination of the fossil very difficult. A few of the most perfect specimens, on being ground and polished, show the laterally directed spiralia with the particular manner in which they are united, resembling those of the genus Athyris. This layer is readily recognized as the equivalent of number 3 of the Jefferson township section, and of number 7 of that of Center township. Number 3 corresponds with number 4 of the Jefferson township exposure, and with number 8

of the Center township section. Number 4 represents number 5 of the Jefferson township exposure, but it does not attain nearly the thickness of the latter, while number 5 of the above section is the equivalent of number 6 of the exposure in Jefferson township. All of the members of the two latter sections belong to the Verdi beds, but their layers cannot be correlated with those of the corresponding phase in the Winter's quarry section, nor with those of any exposure that is found in the eastern portion of the county.

About one mile east of Lowell, in Baltimore township, the bed and banks of a stream, on the north side of the wagon road, show the following section:

		FEET.
7.	Reddish colored clay, containing gravel...	6
6.	Layer of impure limestone, rusty brown in color and bearing no fossils..........	2
5.	Layer of brown magnesian limestone, similar to number 4 below	4
4.	Layer of magnesian limestone containing traces of fossils in the form of casts. The weathered surface of the layer shows obscure lamination planes	2½
3.	Bed of brown magnesian limestone in layers three to seven inches in thickness and containing imperfect impressions of Brachiopods and Fenestelloid Bryozoa.	3
2.	Fine-grained magnesian limestone, brown in color, the layers one to three feet in thickness	[illegible]
1.	Bed of variable limestone, partially [illegible] covered and concealed down to the geode bearing shales of the Keokuk [illegible]	[illegible]

The rocks embraced in the section given above belong to the Springvale beds of the Saint Louis stage. They probably correspond with the Warsaw limestone as described by Mr. Worthen in Hall's Iowa Report*, but none of the species of the fossil Archimedes, which Worthen found conspicuous in the rocks of that group, were found in this exposure. All of the fossils that occur in these layers are in the form of casts, either of the exterior and of the internal portion of the shells, and are too imperfect and fragmentary for satisfactory identification. The small *Lithostrotion canadense*, so characteristic of this horizon, may be

*Hall: Geology of Iowa, Vol. I, part 1, p. [illegible]

county, was not seen *in situ* in any of the above layers, but it is frequently encountered in the bed of the neighboring streams where it has weathered out from their banks at a corresponding horizon.

The rocks of this division have here attained the greatest development of any exposure found within the county. They reach a depth of over thirty-five feet, while the average thickness of the beds of this phase would not exceed twenty-five feet.

As above described, the rocks at this place are uniformly fine-grained and dolomitic in character. They are very durable and furnish a splendid quality of stone for foundation work and heavy masonry. It is from these layers that the stone used in the construction of the piers of the wagon bridge across the Skunk river at Lowell was taken. Owing to the oxidation of the particles of iron that are disseminated through these rocks, they usually assume a yellowish brown color when long exposed to the air. This fact renders their use objectionable for purposes in which a fine appearance is especially desired.

Twenty miles directly north of the Lowell exposure, and separated from it by almost the length of the county, there is an interesting quarry in the Se. ¼ of section 4 of Scott township, about one mile northeast of the town of Winfield. At this place an exposure just north of the road on land owned by Mr. G. W. Wilson shows the following succession of layers:

		FEET.
5.	Clay of a reddish brown color containing gravel	5
4.	Bed of fine-grained, fissile limestone, light gray in color, the layers one to three inches in thickness, and containing but few fossils	4
3.	Bed of rather soft, fine-grained sandstone.	6½
2.	Bed of bluish gray limestone, the layers three to eight inches in thickness near the top, but increasing to as much as twelve inches near the base. The layers are separated by shaly partings which contain numerous fossils	10
1.	Yellowish brown magnesian limestone perforated with irregularly shaped cavities to the base of the exposure	2

Number 1 in the above section is of a stronger yellow color than

the magnesian limestone usually met with over the county. It is less compact and contains a greater number of cavities which resemble water worn passages. No traces of fossils were found in the rocks of this member. Number 2 is a bed of gray limestone. The narrower layers are somewhat shaly and weather easily into thin fragments, but the thicker portions are compact and durable. The shaly bands are very fossiliferous, among which the following forms are abundant:

Zaphrentis spinulosa E. & H.
Lithostrotion canadense var. proliferum Hall.
Syringopora sp. undt.
Archaeocidaris sp., spines and plates.
Fenestella, sp.
Dielasma formosa? Hall.
Spirifer keokuk Hall.
Eumetria marcyi Shumard.
Athyris subquadrata? Hall.

Number 3 is a bed of somewhat incoherent yellowish brown

FIG. 50. Exposure of Saint Louis limestone near Winfield, Iowa. The lower layers contain the loosely growing form of Lithostrotion.

sand which contains a small amount of calcareous matter. This bed is succeeded rather abruptly by layers of fine-grained limestone which contain but few fossils as compared with number 2 below. It consists of narrow layers of compact, light colored stone, which bear no bands of softer shaly material between them, as do the layers of limestone of the lower member.

The group of strata found here is different from that of any other exposure in the county so far as known. The assemblage of fossils which they contain is also unlike that found in the rocks at any other point over the area. Professor Stuart Weller, of the University of Chicago, to whom the fossils of these beds were submitted, regards them as indicating a Saint Louis fauna.

The presence of *Lithostrotion canadense* would suggest the Springvale horizon, but this coral, which here occurs in abundance, is at this place never silicified and is always either in a simple or very loosely growing form. It is usually even more loose and independent in its manner of growth than the species *L. proliferum* as figured and described by Hall* in his Iowa report. At every other point over the county where this fossil occurs, it is the closely growing massive form that is found, and its calcareous matter has always been replaced by silica. Further north, in Washington county, Mr. Bain found the rocks of the Springvale division to consist largely of limestones and shales† with scant development of the magnesian phase which predominates further west and south. He speaks of finding a few fossils in these rocks, but does not state the particular forms that were collected.

It seems probable that towards the margin of the Saint Louis limestone the rocks of the lower division loose the massive, magnesian character which they present further to the south and west; and that in the shallower waters the deposits were thinner layers of limestones interstratified with beds of shale. Under these conditions for some reason the coral Lithostrotion did not thrive so vigorously as it did in the deeper waters at a greater distance from the margin. As a consequence it remained either simple or very loosely branching in its mode of growth. The conditions were not so favorable, either, for the ready passage

* Hall: Geology of Iowa. Vol. I. pt. 2, p. 668, plate XXIV, fig. 6.
† Bain: Iowa Geol. Surv., Vol. V, p. 148.

of percolating waters, or for the charging of those waters with silica, as in the beds found in the southern portion of the county, hence the fossils here are all in their natural calcareous condition.

This isolated outcrop is separated from all other rock exposures by several miles of drift-covered prairie. The nearest rocks that appear at the surface are found about seven miles northeast of this point in Louisa county. Here, in a quarry worked by Mr. John Wasson, in the south bank of Long creek, are exposed the crinoidal layers of the Burlington limestones. About the same distance east from Winfield, near Morning Sun, rock exposures along Honey creek also reveal layers of crinoidal limestone, which contain numerous fossil forms characteristic of the Burlington sub-stage. Towards the south there are no rocks encountered short of the upper layers of the Saint Louis limestone ten miles distant; while the rocks first met with towards the west from the Winfield exposure occur in the northern part of Wayne township and belong to the Verdi phase of the Saint Louis.

In view of the evidence furnished by the fossils, and from the slight lithological resemblance of these rocks to those of the Springvale division as developed further north, nearer the margin of the Saint Louis limestone, and considering the fact that this exposure lies some miles nearer the margin of the deposits of this stage than any other exposure within the county, the most probable interpretation would seem to be that the rocks which appear in the quarry near Winfield belong to the Springvale division of the Saint Louis stage, and that they were deposited contemporaneously with those exposed in the section given from near Lowell.

From a comparison of the sections given above a general section of the rocks of the Saint Louis stage, as they are developed within the county, showing the lithological characters and the maximum thickness of the strata of each of the divisions, may be constructed as follows:

		FEET.
11.	Rather soft, bluish gray shale, very fossiliferous, containing *Zaphrentis pallaensis*, *Productus marginocinctus*, *Rhynchonella ottumwa*, *Dielasma turgida*, *Spirifer keokuk*, *Athyris subquadrata* and *Allorisma marionensis*	6
10.	Fine-grained, compact, ash-colored limestone in layers twelve to twenty inches in thickness, containing *Productus tenuicostus* and *P. ovatus*	5
9.	Compact, gray colored limestone evenly bedded, the layers three to eight inches in thickness, the partings of shale between the layers containing numerous individuals of *Rhynchonella ottumwa*, *Dielasma turgida* and *Spirifer keokuk* ..	7
8.	Layer of very hard, fine-grained, light gray limestone	½
7.	Three flagstone layers, six, three and five inches in thickness respectively, clay seams separating the layers containing numerous fossils similar to No. 9 above	1 ½
6.	Layers of fine-grained, light colored limestone two to three feet in thickness, containing but few fossils	8
5.	Brecciated bed of fine-grained, gray, nonfossiliferous limestone	5
4.	Irregular bed of sandstone and shale intermingled in places with narrow layers of oolitic or impure limestone..........	12
3.	Band of chert in the form of a solid layer of flint	1 ½
2.	Disturbed beds of limestone, sandstone and shale, much broken and very irregular..	19
1.	Impure limestone, usually dolomitic, yellowish brown in color, the layers varying from a few inches to four feet in thickness, containing the casts of a few fossils, but especially bearing the silicified coralla of Lithostrotion	35

As will be seen from the above section, the rocks of the Saint Louis stage here have a maximum thickness of one hundred feet. Numbers 7 to 11 inclusive represent the Pella beds with an aggregate thickness of twenty feet. The shaly bed at the top has been eroded over the greater part of the area. The character of the rocks and the uniformly regular arrangement of the layers

in this division are constant all over the county wherever these rocks are exposed.

Numbers 2 to 6 inclusive constitute the Verdi division with a maximum thickness of forty-five feet. The beds are usually very much broken and exceedingly variable as regards their lithology, their arrangement and the degree of disturbance.

Number 1 belongs to the Springvale division, attaining at one point a depth of thirty-five feet. The rocks are usually a brown magnesian limestone, in rather thick layers, and yield but few fossils besides the diagnostic coral *Lithostrotion canadense,* Cast.

The beds exposed in the quarry near Winfield differ from the typical deposits of the Springvale division with respect to the general character of the rocks and the fossils which they contain. Their stratigraphical position is not certainly known, but they are thought to represent a different phase of development of the same division.

The fauna of the Saint Louis is much less rich in the variety of its forms than that of the Keokuk limestone, but it is not excelled in the abundance of individuals. The Pella beds are preeminently the fossil bearing phase. The layers of the Verdi division seldom yield any forms whatever. The Springvale phase is more prolific. Including the beds of the Winfield exposure, this division furnishes a goodly number of species, some of which occur in great abundance. The following is the list of the fossils of the Saint Louis limestone as found in Henry county:

Zaphrentis pellaensis Worthen.
Zaphrentis spinulosa Ed. and H.
Lithostrotion canadense Cast.
Lithostrotion canadense var. proliferum Hall.
Syringopora, sp.
Chaetetes, sp.
Archaeocidaris, sp.
Fonestella, sp.
Productus marginocinctus Prout.
Productus tenuicostus Hall.
Productus ovatus Hall.
Dielasma turgida Hall.
Dielasma formosa Hall.
Spirifer keokuk Hall.

Eumetria marcyi Shumard.
Athyris subquadrata Hall.
Athyris, sp.
Allorisma marionensis White.
Rhynchonella ottumwa White.

Upper Carboniferous or Pennsylvanian Series.

The deposition of the rock materials of the Saint Louis stage was brought to a close by a crustal movement which carried this portion of the state above the sea. Succeeding this elevation for a long interval the area was a land surface, subjected to all the weathering influences of the atmosphere and the erosional effects of meteoric waters that prevail over land areas at the present time. As the land rose higher the streams wore deeper their valleys in the hard layers of the Saint Louis limestone until in some places they reached a depth of at least ninety feet, and probably much greater. At the close of this long period of elevation there was a subsidence which once more buried the region beneath the waters and initiated the deposits of the Upper Carboniferous series.

Numerous exposures of the rocks of this series are found over the southern and western portions of the county. These deposits consist for the most part of beds of yellowish or brown colored sandstone. However, the occurrence of narrow seams of soft, earthy coal with accompanying bands of shale is not infrequent in the townships of Salem, Tippecanoe and Trenton. All of the materials belong to the Des Moines stage of the series. They were probably spread over the entire area and may originally have covered this portion of the state to a depth of many feet. The very long period that again intervened between the laying down of the Upper Carboniferous rock materials and the invasion of the first ice sheet, which buried them deeply out of the reach of erosion, sufficed to allow most of the region to be entirely denuded of its sandstones. Only such portions of these rocks were preserved as were deposited in old stream channels that were carved in the beds of Saint Louis limestone prior to the deposit of the Upper Carboniferous materials.

At no point within Henry county are the Des Moines sandstones

exposed where the eroded edges of the layers of Saint Louis limestone do not outcrop in a horizontal position at a higher level than the bed of sandstone, either immediately adjacent or only a short distance away.

The consideration of a few typical sections will make clear the character of these deposits and the relations which they sustain to the older limestones of the Saint Louis. Many of the present streams have found and established themselves within old valleys which were cut into the Saint Louis limestone and were afterward filled with the sandstones of the Upper Carboniferous. Finding it easier to carve their beds in the soft sandstone than in the harder limestone, which forms the surface rock over the greater part of the area, the streams have frequently exposed along their beds and on their banks these sandstones of the Coal Measures. A small ravine in section 5 of Salem township shows numerous outcrops of the materials of the Des Moines stage, of which the following is a representative section:

	FEET.
3. Gravels and bowlder clay of the Kansan drift	$3\frac{1}{2}$
2. Layer of soft sandstone grading downward into a narrow band of shale	4
1. Bed of impure, earthy coal, rather soft and crumbling easily, the layers one to three inches in thickness	3

A few rods further down the stream there is an outcrop in which the coal is a better quality. The bed is three and one-half feet in thickness, and the layers vary from one to four inches. The coal is much harder and contains less earthy matter than that of the above section. This coal band is immediately overlain by about six feet of bowlder clay, both the sandstones and the shales having been removed.

Twenty rods north of this latter exposure, the edges of evenly bedded layers of fine-grained, white, fossiliferous limestone outcrop on the hillside twenty-five feet above the level of the band of coal.

In the banks of a stream about one-half mile west of the house of Mr. Wm. Spray, near the central portion of section 32, Tippecanoe township, the sandstones, shale and coal of the Des Moines stage are exposed. The coal at this point is of about the same

the former stream about five rods south of the exposure, the layers of the Pella beds in their normal arrangement and succession are passed over.

Along Rock creek, in the Sw. ¼ of the Sw. ¼ of Sec. 18, Salem township, at a point where the stream makes an abrupt turn to the north, there is exposed in a bluff about fifteen feet of the Coal Measure sandstone. At the top of this bluff there is an offset about eight feet in width back to a ledge of Saint Louis limestone which rises to a height of seven feet above the sandstone. This ledge of limestone represents the east wall of an old valley in which the sandstone was laid down. Many other out-

FIG. 53. Exposure along Rock creek in section 18, Salem township, showing the sandstones of the Coal Measures abutting against a ledge of Saint Louis limestone.

liers of the Des Moines sandstone occur over the county wherever the indurated rocks reach the surface, but they do not differ in any essential way from those described.

Pleistocene System.

After the elevation which closed the Upper Carboniferous epoch, the surface of the area which comprises Henry county remained permanently above the sea. During the whole of the succeeding geological era and through the greater part of the next following it was subjected to the wasting effects of the agents of erosion. During this enormous interval deep river valleys and stream channels were carved in this surface, forming a dendritic drainage system similar to, but much deeper than that which dissects the surface today. In the early part of the Pleistocene period ice sheets moved down from the north and covered with their mantle of superficial materials all of this portion of the state. These deposits were laid down unconformably over the eroded surface of the Carboniferous rocks, burying them to a depth which in places reached at least 175 feet.

The glacial series is represented in Henry county by two distinct drift sheets known as the Kansan and the Illinoian, besides the later deposits of loess and alluvium.

KANSAN DRIFT.

All of the drift exposed at the surface in Henry county, except a narrow strip along the eastern edge of the townships of New London and Baltimore, belongs to the Kansan stage. The Kansan is the second drift sheet which overspread the greater portion of Iowa. It has a wider extension than the first, or pre-Kansan, and so has concealed the latter from observation, except in a few favored places, where excavation or erosion has revealed its presence. The pre-Kansan drift was probably spread over all of this region, but there are no natural sections in which it is exposed within Henry county. At different points the wells which have been put down in the drift encounter a layer of sand, or a soil horizon, occupying a zone between two beds of bowlder clay. This soil horizon was once a land surface and represents the interval between the retreat of the pre-Kansan ice and the invasion of the Kansan. The beds of sand were laid down along the channels of the streams at the margin of the melting ice. These sand beds were covered by the drift brought down by the Kansan ice

sheet. They form water bearing layers at no great distance below the surface, and are the chief source of the water supply for the shallow wells.

The Kansan drift, where exposed in a thick bed, is a bluish clay containing numerous small bowlders varying in size from one or two to ten or twelve inches in diameter. Occasionally bowlders two to four feet in diameter are found and one was seen as much as ten feet across. The larger bowlders are usually reddish gray granites, but many of the smaller ones are of dark colored, fine-grained trap known as greenstone. Many of them present beautifully glaciated surfaces, showing that during some portion of their long journey they had been carried along in the ground moraine. Fragments of limestone are also frequently found imbedded in the clay.

The surface of the Kansan drift where it is exposed in the ravines along the roadsides is leached of all of its calcareous matter. It usually has a red or reddish brown color for a depth of from one to three feet, grading downward through yellow to the typical bluish color of the unchanged drift. This red color near the surface is due to a change in the form of the iron which is contained in the clay. The ferrous oxide or carbonate of the blue clay has been changed to the form of limonite, or hematite, where long exposed to the oxidizing influences of the atmosphere.

BUCHANAN GRAVELS.

At various places over Henry county there is exposed above the Kansan drift a bed of interstratified sand and gravels. The deposit is not uniform in depth, nor is it continuous over wide areas. The pebbles are usually small, rarely exceeding three inches in diameter, and are generally rounded and much waterworn. These materials were deposited soon after the drift was spread out, before any change had taken place in its surface. They record the action of swift and variable currents in streams which carried a large volume of water. The stratification is very irregular, finer sand and coarser gravels not being sorted so perfectly as is usually the case with waterlaid materials. The beds were probably laid down along the channels of the streams which carried away the waters which resulted from the melting of the Kansan ice.

ship, in Des Moines county. This conspicuous line of hills overlooks Canaan township along its entire eastern border. It then bends further eastward and is soon lost to sight from the limits of Henry county.

The rounded ridges of morainic material have a width of from one to one and a half miles. In Henry county they are best marked on the level land which lies between the broken country bordering the Skunk river and the hills near the headwaters of Mud creek, and again on the prairie north of the latter hills to the point where they pass out of the county in section 13 of New London township.

This moraine marks the western extension of the Illinoian drift over this area. It is much more conspicuous and well defined than is the distinction between the materials carried by the Kansan and the Illinoian ice sheets. Red jasper bowlders, which are not found in the former, are not infrequent in the latter, but the majority of the granite and greenstone bowlders which occur in one resemble in every way those found in the other. The ferretto character of the oxidized surface of the clay and gravels is common to both, as is also the fact that to a few feet in depth the surface materials of both drift sheets are leached of their calcareous matter.

THE LOESS.

The loess is usually a yellowish, uniformly fine-grained deposit whose constituent particles resemble very fine silt. This material forms a mantle over the surface of the entire area except where removed by streams. Its characteristic color is obscured over the prairie portions owing to the presence of the greater amount of carbonaceous matter in the surface soil, but the fine-grained texture and the absence of pebbles or bowlders are still maintained. Over the greater portion of the region it is light gray in color and only a few inches in depth, but at a few points it attains a thickness of several feet.

In making some recent improvements in the road-bed of the Chicago, Burlington and Quincy railway, cuts have been made through some of the hills in the vicinity of Rome, which yield instructive facts relative to the development of the loess over this

FIG. 55. Deposit of loess overlying Kansan drift, near Rome, Iowa. 1. Drift. 2. Loess.

area. The following section is exposed in the Se. ¼ of section 4, Tippecanoe township, on the east bank of the Skunk river:

		FEET.
2.	Fine-grained, typical loess, light yellow in color and very rich in fossils	25
1.	Reddish colored clay, with pebbles and bowlders of granite and masses of limestone intermingled	8

In the eastern part of section 3 of the same township, a new cut shows the following beds:

		FEET.
3.	Light yellow, fine-grained loess	10
2.	Bed of interstratified sand and gravels	12
1.	Bluish colored till	6

In the sections given above the surface of the Kansan drift shows a reddish, oxidized band which conforms to the contour of the hill. The thickest portion of the loess is on the crest and the westward slope of the hill, and the thinnest portion of the oxidized band lies immediately below the deepest deposits of loess. In the first section some traces of stratification appear in

the loess, the lines, however, are not horizontal but conform in some measure to the slope.

The term "bluff material" is especially applicable to the loess in Henry county, as the thick deposits are found only on the hills along the east bank of Skunk river. It is only these thick beds that carry fossils. The numerous fossil forms which occur here in the loess mostly belong to the genera Succinea, Zonites, Mesodon and Pupa. The loess was evidently a later deposit than the drift, as is shown by the eroded and oxidized surface of the latter underlying the thick beds of the former.

The origin of the loess and the manner of its deposition are questions which as yet scientists have been unable satisfactorily to explain. There are two hypotheses given which might account for the condition of the drift and the presence of the overlyin loess as here exposed. One is that for a long period succeeding the Kansan ice invasion the drift was exposed at the surface and subjected to erosion and to the oxidizing influences of the atmosphere. After this long interval a downward movement of the crust brought this portion of the state near the base level, so that the slow moving water of the expanded rivers carried and deposited only the finest silt over the surface of the drift.

The second explanation is that this fine-grained material was carried by the wind and slowly laid down on the crest and sides of the hills and in the valleys and over the prairies; wherever vegetation or leeward slopes or obstructions of any kind would catch and conceal from the air these fine particles of dust. According to the latter view, the erosion of the drift and the oxidizing of its surface went on contemporaneously with the deposit of loess. The extreme slowness of the deposition of the materials by the wind would suffice for the changes in the surface of the drift to have reached their present depth before the covering of loess would be sufficient to protect it from the further action of the atmosphere. The latter view would seem to best explain the relation between the drift and the loess and the condition of both as they appear in Henry county.

ALLUVIUM.

The waters of Skunk river and Big Cedar creek flow through a broad valley which within Henry county would average about

one mile in width. The surface of the greater portion of this flood plain has received a rich deposit of loose sediment consisting of sand and finer particles of soil. Big creek also in all of the lower part of its course flows through a rich alluvial plain. In places along the Skunk river this material is composed of beds of sand, and along the margins of the valley of all of the streams the true river laid deposit is more or less mixed with the downwash of the loess and clay from the hills. Over the greater portion of these plains the sediment is a true alluvium, which responds generously to cultivation and ranks among the most productive farm lands of the county.

Alluvial deposits occupy areas of varying extent at numerous points along many of the smaller streams. Wherever their channels have been extended sidewise and narrow bottom lands formed these fluviatile materials have been laid down.

Deformations

The rocks of Henry county have been subjected to strains of lateral pressure sufficient in many places to produce a slight folding of the strata. There are evidences of this appearing in the outcrops of Keokuk limestone, where these rocks are exposed at the surface at different levels and at isolated points widely separated from one another. The strata of the Keokuk, however, in the limited areas which are exposed, seem to lie horizontal and it is possible that the absence of these rocks at the same level over intervening areas may be due entirely to erosion rather than to any folding of the strata.

Slight deformations occur at numerous points in the Verdi beds of the Saint Louis stage. The most of these are of a local nature, due usually to the intercalation of layers of sand or shale, or to the rapid thinning out of some of the beds in this very variable deposit.

The layers of the Pella division show some marked examples of folding. The disturbance in these beds, however, did not reach a very great depth, never involving the underlying rocks of the Verdi. The strains were not sufficient to cause any fractures or dislocations of the strata over the area, but resulted in the gentle flexing of the layers, as described under the discussion of the

Pella beds in the present report. The axes of the folds trend nearly in an east and west direction, their vertical height not exceeding five feet in the places where they were well exposed.

Unconformities.

The rocks of Henry county present several instances of unconformity. There are indications that the Saint Louis limestone was laid down unconformably upon the underlying beds of the Keokuk. The presence of the former overlying the hard limestone phase of the latter at Webster's mill, while on Mud creek the same rocks of Saint Louis age rest upon the deposit of Geode shales, would seem to indicate the erosion of these shales in the former exposure before the Saint Louis beds were laid down. The outcrop of the Keokuk rocks at different levels while in the intervening areas the same level is occupied by the Saint Louis deposits, would also be an evidence of unconformity. There is a possibility, however, that here near the margin of the Geode shales, those deposits thinned out locally, and that this bed was never laid down over the surface of the region of Webster's mill. It is possible, also, that a slight folding of the strata might account for the presence at the surface of the Keokuk limestone at different levels. However, since those layers wherever exposed have a horizontal position, and since the Saint Louis rocks are known to rest unconformably upon those of the Augusta further to the north and west, it is probable that over this area also the same relations prevail.

A second unconformity occurs between the rocks of the Saint Louis stage and the overlying sandstones of the Des Moines. In multiplied instances these sandstones may be seen occupying the old valleys carved in the rocks of the Saint Louis during the long interval that elapsed between the laying down of the latter and the deposit of the former. During this interval the land over Henry county stood higher than at present, as is shown by the fact that in many places the present streams which follow those old valleys have not yet cut their channels through the beds of Upper Carboniferous sandstone. The oldest drift sheet of the glacial series deposited its materials over the eroded surface of

indurated rocks, and the till of each of the succeeding ice sheets was laid down uncomformably upon that of the preceding.

ECONOMIC PRODUCTS.

Soils.

The soils of Henry county must always constitute its greatest source of wealth, and in this respect this favored region is excelled by few areas of equal size within the state.

Over all of the prairie surface the soil is dark colored, rich and deep, containing an abundance of carbonaceous material. The land usually has sufficient slope to permit a tolerably free surface drainage, although in the townships of Wayne, Scott, Canaan, and the northern portion of Marion and New London, the farms are mostly underdrained by means of tile which removes the excess of water from the soil and keeps the surface porous in the seasons of great rainfall.

Extensive prairie areas are also found in the townships of Jefferson and Salem over the divides which separate the principal water courses. Bordering the main streams and their larger tributaries, the land is much broken; the hill-slopes are covered with a yellowish loess clay which originally supported a heavy growth of timber.

These slopes in many places have been denuded of their forests, but the clayey soil, which too often has been put under the plow, is the least productive land of the county. It is a great mistake ever to have attempted to crop these clayey hillsides. They should have been left for the perpetuation of our fast vanishing forest areas, or in lieu of that, they are far more profitable as pasture lands than for purposes of tillage. If the ground remains undisturbed, the native blue grass rapidly covers the surface and prevents further wash after the forests have been removed.

A third type of soil is the rich alluvium which is found along the valleys of all of the larger streams. When not too sandy, this soil ranks second to none in its productiveness and ease of cultivation.

Coal.

In Professor Hall's report on the Geology of Iowa* in 1858, Mr. Worthen says: "Several outliers of coal occur in Henry county on the east side of Skunk river and Big Cedar creek; but none of them have as yet yielded a profitable coal seam, nor is it probable they ever will." In another place he states, "The only coal lands that promise anything like a profitable coal seam are those lying west of Skunk river and Cedar creek."

During the earlier history of the county large quantities of coal were annually taken from the Coal Measure deposits of the latter area mentioned by Mr. Worthen. The more important mines were opened in the western portion of the townships of Salem and Tippecanoe. These coal beds are all very local over this area, as is seen from the position occupied by the deposits of the Des Moines stage. The seams are narrow and the quality of the coal rather inferior. None of these coal deposits have been worked within the county for a number of years. It is possible that as the supply of fuel becomes more scarce and its cost is increased, the work of getting out coal from these beds may be resumed, and the Coal Measures may yet be a source of wealth to the people of the county.

Building Stone.

Stone suitable for common foundation work and general masonry is found in abundance over all portions of the county in which the indurated rocks are exposed. The hard layers of the Keokuk limestone would furnish an abundant supply of building material, but so far as known there are no quarries opened in these beds within the area. The Springvale division of the Saint Louis stage yields a very durable stone. It is dolomitic in character and so is less readily acted upon by the acids of the atmosphere and weathers more slowly than the common limestone. These layers are quarried at various points in Baltimore township and to some extent in the townships of Center and Jackson.

The compact layers of the Pella beds furnish a good quality of stone and are so generally distributed that they constitute the

* Hall, Geology of Iowa, pp. 211-214. 1858.

Sand.

Sand suitable for building purposes is found in great abundance at a number of places in the county.

The soft sandstone beds of the Verdi division of the Saint Louis are sometimes used. The best deposits occur at various points along the flood plain of the Skunk river and of Big Cedar and Big creeks, where almost unlimited quantities can be obtained. The wind formed hills of sand which occur in Jefferson township are also an important source of supply. Very little of this material is met with over the northeastern portion of the county.

Clay.

The beds of the Upper Carboniferous series in a few places afford some materials suitable for the manufacture of the finer grade of clay goods, but they are too thin and cover too small an area to be a very important source of supply. They are not at present worked at any point within the county.

The deposits of the Pleistocene furnish an unlimited amount of raw material suitable for the manufacture of the common, coarser kinds of clay products, such as construction brick and drain tile. These deposits cover the entire surface of the county and make possible the burning of brick and tile at almost every locality over the area. Almost every small village has its brick kiln which is supplied with inexpensive machinery and is not worked continuously, a supply being burned as often as the demand requires. The brick and tile are made from the loess clay which covers the drift in some places to a depth of several feet.

Turley Brothers.—In the southeastern part of Baltimore township is located the pottery works of Turley Brothers, where a few men are employed during the summer months in the manufacture of the coarser articles of earthenware, such as crocks, jars and jugs of various kinds. There is no modern machinery employed at this place, but the work is almost all done by hand. The market is mostly local, the products being hauled by wagons to the neighboring towns. The clay which is used comes from drift which is probably of Illinoian age. It is light colored, con-

taining but little sand or pebbles and is somewhat greasy to the feel.

Winfield Brick and Tile Co.—At the town of Winfield there is a brick and tile factory operated by Mr. Beecher Pierce. The clay is furnished by the loess which is exposed in the pit to a depth of about eight feet. It is underlain by a bed of sand and gravels. This clay contains a lower percentage of iron than that used at New London which gives to the products a somewhat yellowish color. The ware is very hard, ringing well when struck with a hammer. The plant includes the main factory building, a drying house, eighty by thirty feet, three round, down draft kilns, and a Brewer & Company tile machine. It has a capacity of from 2,500 to 10,000 tile per day. Ten men are employed from April 1st to January 1st of each year. Home trade is the main market, the wares being distributed over a radius of ten or twelve miles.

New London Brick and Tile Works.—Brick and tile are manufactured at New London, Iowa, by Mr. C. E. Magers. The factory was established in 1891 and employs fifteen men throughout the year. The plant embraces two round, down draft kilns, a steam drier and a main building 90 by 120 feet containing two stories, which give 15,000 square feet of floor room. The combined output of tile and brick has a value of about $10,000 annually. The clay is taken from a bank of loess ten feet in depth. The market is largely local, a part of the products also being sent to different points in the neighboring counties of Lee and Des Moines.

Water Supply.

The waters of Skunk river and of Big Cedar and Big creeks continue to flow throughout the year, furnishing an excellent water supply to the areas through which they pass. The most of the smaller streams are usually dry during a portion of the summer months. Wells sunk in the superficial deposits furnish an abundant supply of pure water at a depth ranging from thirty to two hundred feet. No deep wells penetrating the indurated rocks have been put down within the county except one at Mount Pleasant,

which is on the grounds of the State Hospital for the Insane. This well has a depth of 1,125 feet, and obtains its water supply from the porous sandstone of the Saint Peter stage.

Water Power.

The Skunk river furnishes abundant water power except during the periods of long continued drouth. This power is utilized by flouring mills at three different points along its course. Merrimac mill is located near the southwest corner of Jefferson township. Oakland mill is near the eastern border of Tippecanoe township, and the Lowell mill is at the village of Lowell, in the southern part of the township of Baltimore. All of these mills run continuously, and are provided also with steam power, which they use during periods of low water.

ACKNOWLEDGMENTS.

In the preparation of the foregoing report, the writer has received valuable information and kindly assistance from many persons. Thanks are especially due to Mr. Frank Leverett, of the U. S. Geological Survey, from whose work the facts relative to the superficial deposits of the county were largely drawn; to Professor Stuart Weller, who kindly identified some difficult invertebrate fossils; to Dr. C. R. Eastman, who named the fishes of the Keokuk limestone; and to Professor Samuel Calvin, whose instruction made possible whatever merit this report may possess. The writer is also indebted to Mr. J. A. Rice, Mr. D. L. Savage and many other citizens of the county who helped to make the prosecution of the field work an enjoyable task. To all of the above the author tends his hearty thanks.

BY

T. E. SAVAGE.

1902.

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

GEOLOGY

OF

CHEROKEE AND BUENA VISTA COUNTIES

With Notes on the Limits of the Wisconsin Drift as Seen in Northwestern Iowa.

BY

THOMAS H. MACBRIDE.

come to distinction as the most fortunate, fertile and prosperous section of a famous state.

These two counties have on the north O'Brien and Clay, counties already described in this series of reports;* on the west Plymouth county, fully discussed in Volume VIII;† on the south they are bounded by Woodbury, Ida and Sac, and on the east by Pocahontas. Each county is exactly square and contains sixteen congressional townships. For purposes of present description the two counties are here associated; but as a matter of fact, they are in many particulars, as the sequel will show, quite as unlike as two prairie counties well could be. Present unlikeness in the present instance, of course, bespeaks different history, and our story is marked by contrasts everywhere and not by comparisons. Cherokee county is more like Plymouth and Sioux; Buena Vista resembles part of O'Brien and Clay and especially the counties farther north. Buena Vista, true to the meaning of its name, has its own peculiar charm; Cherokee presents a landscape so varied and yet withal so moderate as to be without a rival in all that looks to agricultural beauty and easy, fortunate husbandry.

PREVIOUS GEOLOGICAL WORK.

These two counties have never hitherto been studied by the naturalist. Dr. White seems to have crossed them and to them devotes something more than a page;‡ but satisfactory study and thorough description were at that time prohibited alike by the state of geological knowledge and by the limits under which Dr. White's survey was made. The part taken by Owen and Nicollet in the discovery and description of this northwest portion of the state has been already sufficiently set forth in these reports.§

PHYSIOGRAPHY.

TOPOGRAPHY.

To an ordinary observer it might seem idle to attempt to find, much less to describe anything of interest in the so-called mo-

* Iowa Geol. Surv., vol. XI, pp. 461, 5c8.
† Iowa Geol. Surv., vol. VIII, pp. 318-366.
‡ Geol. Surv. of Iowa by Charles A. White, vol. II, pp. 225-6, 1870.
§ Iowa Geol. Surv., vol. X, p 191, and vol. XI, p. 465.

notonous prairie of our northwestern counties. At first sight to most people one prairie is exactly like another, and a "rolling" landscape in one locality is simply the counterpart of "broken" country twenty-five or fifty miles away. But let the attentive observer once traverse the prairie with the special intent of study or comparison and his views of monotony and of prairie topography in general will undergo remarkable change. Especially will this be the case if the path of his investigation chance to cross the two counties now the theme of description and discussion.

Let our traveler, for instance, enter Cherokee county from the west, near the middle of its western boundary and pursue a course directly east across Cherokee and Buena Vista counties; at first he will encounter a comparatively level plain; "gently rolling," he would say. But as he proceeds the hollows deepen and he presently encounters the broad fine valley of the Little Sioux, west fork, stretching southward. Again he ascends. The country once more becomes nearly level only to break again into the succeeding south-extended valleys of Willow and Rock creeks; until at length it reached the deep trough of the Little Sioux itself, a great eroded channel, with high, bowlder-strewn bluff-like banks, much too large indeed for the present diminished stream. Crossing this the western topography is repeated. The several branches of the Maple succeed, each showing an erosion valley leading south, perfectly draining the meadows and separated by long low ridges, sometimes of such width as to make the lifted meadows and fields almost perfectly flat, a plain and yet a water-shed. Such or similar topography carries us a little distance across the eastern boundaries of the county. We enter Buena Vista. For several miles the traveler notes little difference; but as he pursues his journey eastward suddenly the scene is entirely changed. He passes over the last broad clay-covered ridge and looking southward may behold the town of Alta, beautifully located and perfectly named, a crest, a summit of older than historic interest. Still trending eastward the traveler presently finds himself confronted by an unexpected swamp, a marsh of unusual extent, sufficient perhaps to deflect the unopened section highway. Beyond the swamp, safely crosssed or

turned by some detour, rises a singular ridge which proves to be made of sand or gravel and is entirely unlike the crests of Cherokee county, as different, in fact, as different can be, precipitous, narrow, soon crossed, landing the traveler by perhaps irregular, abrupt descent upon a plain again, which curiously enough shows no erosion, or only the slightest, has no valleys and no streams, no ridges with their sloping sides as water-sheds, but instead a confusion of irregular mounds, some perhaps worthy the name of hills, others simply swells or low, abrupt, causeless elevations, a few feet in height, on which perchance the farmer has pitched his farmstead, as if to keep out of the general wet. Some of the hills are so large and mound-like as to have attracted everybody's attention; they are real knolls, almost dunes, with a trend southeast, northwest.

As the traveler proceeds great marshes again obstruct his course, affecting not sections only, but sometimes a township entire; there are no bridges, only here and there a culvert through which the road-makers have coaxed part of the slough water from one side of the road to the other, it matters little in which direction. To the south are the beginnings of the Raccoon river, small creeks which wind about through lands much better drained. To the north the mounds and ridges are again the features of the landscape, stretching off about the town of Marathon, becoming more and more prominent as we approach again the county line.

The topography of the country is an inscription written in large letters, it is true, and occasionally somewhat obscured and blurred, since it often overlies similar earlier inscriptions—becomes a palimpsest in most real sense—but an inscription it still remains, legible enough once we find the key and take the pains to decipher line after line.

These topographical differences between two adjoining sections of the country are accordingly no accident. We should find very similar contrasts if we drive from Sac to Calhoun, or from Crawford into Carroll county. We have before us two distinct topographic plans or types, each bringing with it a history of its own. The topography of Cherokee county is erosional; that of Buena Vista county, morainic. The first represents the gen-

eral effect of long continued weathering, the washing of storm-waters down a broad and gentle slope; the second shows the scattered piles of drift material and detritus deposited by some great glacier or ice-sheet, once dominant so far south and west, its debris as yet little affected by the rains and snows of the centuries that have since elapsed.

In our present problem erosion finds extremest illustration in the deep-cut valley of the Little Sioux; the drift, or morainic topography is emphasized when the swamps and marshes deepen into lakes, as in the counties immediately to the north of us, or when the hills and kames rise to ridges or knobs of considerable height, as at Ruthven or in the vicinity of Ocheyedan; in our present limited district there are really no morainic lakes, though plenty of swamps, and the morainic elevations are generally low and insignificant.

Of course, we have not overlooked Storm lake. Here is a body of water fine enough and large enough to deserve not mention only, but a more or less complete description. From what has been said and from accounts heretofore given of Spirit lake and Okoboji* it is evident that Storm lake belongs in some way at least to that great series or chain of fresh water glacial pools that extends from far northwest in Minnesota and South Dakota all the way to Wall lake in Iowa and the pools of Green and Dallas counties farther south and east.

One of the largest of our glacial lakes, Storm lake, is strangely enough one of the most shallow. Its extreme length is about three and one-half miles; its greatest breadth about two miles. The shores are low and generally even with several sandy beaches. Bowlders formerly decorated the whole margin, but especially the northern and eastern rim, as with an ornate wall, but these have mostly been long since hauled away by enterprising builders. The bottom of the lake is, however, reported to be paved with stone in many places, and here and there along the shore an erratic block of unusual size may yet be seen. The greatest depth of the lake from all accounts does not exceed fifteen feet; the outlet, once a marshy slough, has long since been closed; the incoming streams are few and of minor importance. The

* Iowa Geol Surv., vol. X, pp. 208-212.

fact is the lake has been slowly filling, probably for a long time, and chiefly by vegetable detritus. Once the lake seems to have stretched away in shallow expanse much farther to the north and west as evidenced by the present reedy, marshy swamp, undrained, extending half way to Alta.

To one accustomed to Spirit lake and Okoboji it is a matter of surprise to see no high hills or mounds about Storm lake. The surroundings are remarkably low, almost flat in fact, with no hills worthy of the name approaching the lake on either side. But the truth is the history of Storm lake is entirely different from that of either of the lakes named. Those are far within the moraine of the Wisconsin drift. Storm lake, on the other hand, is at the very limit of the same drift-sheet. It would seem to be the remnant of some preglacial valley, part of the drainage system of this country before the Wisconsin ice came on; or it may represent part of the drainage channel that at one time lay along the glacier's front, choked up at length by the extension of the ice below, that is, toward the southeast. The drainage, never very vigorous here, since, as we shall see, most of it went north by way of Brooke's creek, was easily checked and Storm lake with its accompanying swamp was the result. That the stream was thus checked is evident from the circumstance that the lake's outlet when all glacial topographic change had ceased was into the Coon river, an intra-morainic stream, and not by way of the glacier's margin. The ice was possibly not very thick here and the morainic materials are proportionately scant. Nevertheless, Storm lake is a beautiful feature of this prairie landscape. Its bright waters attracted the pioneer; nor are they less charming to the thousands of people who now find happy homes about its curving shores. Its unprotected surface and its shallowness expose the waters of the lake to the full violence of the wind. These are stirred to the very bottom, producing the wildest effects in both waves and color; hence the name.

The Little Sioux valley, the topographic feature of opposite type, is interesting for several reasons. It is a great channel cut through drift, and although recent as the story of Iowa goes, is yet far older than Storm lake or any of the morainic topography of Buena Vista county. When the glacier lay on all the plains to

the east and north, the valley of the Little Sioux, as it appears in Cherokee county today, broad and deep, did its part in carrying away the waters from the glacier's front, the constantly melting margin. Indeed the valley seems to have been more than once nearly choked by deposits of Wisconsin gravel and perhaps in the upper parts of its course with ice. Especially north of Cherokee the banks of the river valley are everywhere marked by gravel terraces far above the flood-plain of the present stream, sometimes as much as a hundred feet above it. Such deposits are not the effect of ordinary erosive process. There is every evidence that the channel of the river had been fully excavated long before these deposits came to place. Sometimes they hang as a simple residue far up on the side of the sloping bluff, as in section one of Cherokee township; again they form great masses and parapets choking up half the valley as in Spring township; sometimes two or three succeeding terraces may be traced, as in section one of Cherokee township. The main part of the city of Cherokee rests upon one of these benches; the Illinois Central railway follows another north of the city. South of Cherokee the deposits are still abundantly traceable but they are as a rule much lower; nevertheless, they affect the configuration of the valley entirely across the county.

The presence of these gravel-trains, for so such deposits are named, affects the topography in yet another way; the gravel has not only in many places filled up and obliterated older erosion features, but it has itself been subject all the while to the processes of erosion. This often brings about a superposition of a newer topography directly against or upon one a great deal older. We encounter evidence of recent change, of newness and youth, where we should naturally expect the reverse. The walls of the river valley to the north everywhere show this. Old tributary streams have been choked across, and new channels later excavated, sometimes, generally indeed, in the direction of the older valley; not always. The banks of Mill creek show all along these same erosion peculiarities; high terraces of gravel cut by recent steep and short erosion channels. The same thing may be observed in the valley of Brooke's creek, especially in Brooke township, Buena Vista county. These gravel banks often give

rise to springs, as in section fifteen in Cherokee township. These are to be explained by the topographic or structural peculiarities just described. Storm waters of the older, generally higher terrace are caught, filtered and allowed to emerge slowly at the last, often far above the level of the present streams. Sometimes the gathering ground is not extensive enough to form a spring of constant flowing stream, and we have simply a hillside seep or bog. Everywhere the gravel along the principal stream has filled the mouths of incoming valleys and then been again cut out, so that the mouth of any tributary valley is apt to be the narrowest part of it.

The effect of this upon the landscape is sometimes very peculiar, often very beautiful. From the hill-top in Morey's field in Spring township of Cherokee county, the view is one of the finest in northwestern Iowa; one of the finest in the whole prairie country. To the north is the far-stretching terrene of O'Brien county; below and close at hand the level meadows of the flood plain of the Sioux, here very wide; east and south great gravel terraces close in the view with sculpture of the most varied, but withal most softened and pleasing contour.

Between the Little Sioux and Mill creek is a wide gravel tongue carved on both sides by recent erosion and presenting everywhere evidence of the newness of its topography. We have already had occasion to mention the topographic differences between Cherokee and Buena Vista counties; but even in Cherokee county the difference in form, in relief, between the steep bowlder-strewn slopes in Cherokee and Cedar townships and the fair and long-sloping, loess-covered hillsides of Rock and Tilden townships is not only patent, but seems sufficiently striking to awaken the intelligent interest of every student, not to say every intelligent farmer.

Everywhere, especially to the northeast, the topography of Cherokee county has been profoundly modified by close association with a topography of an entirely different character as will appear in what is here to follow. The topography indeed seems to be all erosional; but the typical and pure sculpture of the erosion model does not appear north and east of Mill creek valley.

DRAINAGE.

The drainage of the two counties is correlated, of course, with the topography, affects it or is affected by it. The drainage of Cherokee county belongs to three distinct systems. Buena Vista county has in large part no natural drainage. Its prairies, however, lie on the great divide of Iowa, and the streams that do serve fall now east, now west, and so enter in one direction the tributaries of the Mississippi, in the other those of the Missouri river. In Cherokee county, except a few localities to the north, the drainage is practically perfect; the general slope is to the southwest deepening and widening channels in the same direction. slowly deepening and widening channels in the same direction. Of these the principal is the Little Sioux river which traverses the county almost diagonally from northeast to southwest. Its valley is wide south of Cherokee city; its banks are generally high and in many places covered with native forest. Where the channel is narrower it is so on account of the vast deposits of gravel already described. Nevertheless, even at its entrance into the county where gravel abounds, the flood plain of the river is still wide enough to afford room for fine meadows and far-extending farms sheltered by high, precipitous, bluff-like banks. The waters of the river are unfailing, but the present rate of erosion, though constant, is small. Only in times of freshet does it appear that there is any cutting at all and then chiefly through the shifting of the current from side to side as is customary along all our prairie streams. Even this erosion is more than made good by the deposit of material brought in constantly from the adjoining cultivated fields. But the impressive feature of the entire course of the stream is everywhere the gravel, omnipresent, hanging along the banks. South of the city of Cherokee the accumulations are for the first four miles found almost wholly on the east side of the stream and are piled against the older banks to a height of forty or fifty feet; below Pilot Rock the situation is reversed. Pilot Rock church stands upon a gravel plain a mile or more in width and possibly thirty or forty feet above the present level of the stream, all west of the river. At Quimby, a few miles farther southwest, the river is wholly west of

the gravel plain, and so on; the stream shifting back and forth to the southern boundaries of the county.

Immediately north of Cherokee city the Little Sioux receives one of its principal tributaries, Mill creek. This is a fine perennial stream which enters the county near the middle of its northern boundary and brings with it the drainage of nearly the whole of O'Brien county. Mill creek has also suffered immensely by deposits of gravel. From section 1 in Liberty township south and east the creek has simply made its way through great piles and banks of glacial detritus that become more and more pronounced as we approach the Sioux.

A high table-land of drift, skirted, west of Cherokee, by the Illinois Central railway, separates the entire drainage area of Mill creek from that of the southern slope of the county. Here, that is, west of the Little Sioux, a series of smaller streams, Fiddle creek, West fork, Rock creek and others, flow in long straight valleys almost directly south, affording ample drainage and in ordinary years a constant supply of water. East of the Sioux the Maple river with its tributaries exhibits a typical prairie erosion-drainage-system. The stream channels seem to reach every part of the terrene, dividing and subdividing, in the most natural fashion, nowhere choked by deposits from without, nor bordered anywhere by gravel trains save those which may be accounted for by causes purely local. The flood plain of the Maple is generally a rich black alluvium of indefinite depth, exposed here and there by an erosion that has followed the cultivation of the valley.

The drainage of Buena Vista county, such as there is, is in almost every way wholly different from that just described. The Little Sioux skirts the county along the north and receives as tributary Brooke's creek and one or two minor streams; the Coon river becomes efficient in some of the southeastern townships; but the entire central and eastern portion of Buena Vista county is without any natural drainage at all. Instead, we have here simply wide marshes and low sand-hills as already described. The valley of the Little Sioux is wide and deeply eroded; probably a valley of erosion in large part, although, as stated in our discussion of Clay and O'Brien counties, that part of the valley

before Linn Grove seems of different history and may be in part constructional. The banks of the river in Buena Vista county are generally precipitous, breaking down suddenly from the common level with short, precipitous, narrow, tributary ravines.

The Raccoon river, or North Coon river, as it stands on the local maps, appears as a considerable stream in Providence township. It is for many miles of its tortuous course perennial, fed by seeping springs and long crooked prairie sloughs, now generally either tiled or at least in process of artificial drainage of some sort. The former, southern, outlet of Storm lake is one of the tributaries of the Coon; another branch takes rise about half a mile north of the lake shore but is cut off from the lake by a low plateau of sand and gravel upon which stands the city.

The most interesting stream in Buena Vista county is Brooke's creek. This stream also takes rise in marshy ground about a mile and a half north of the lake and flows almost directly north to the Little Sioux. Flows, did we say! Flows is a term too strong by far. For the greater part of its course Brooke's creek consists simply of a succession of marshes by nature imperfectly

FIG. [illegible]. View at the mouth of Brooke's creek, [illegible]

mined, and originally [illegible] to be recognized as a [illegible] at all. Northward we have a more definite stream and channel, [illegible] as we approach the Sioux the usual erosion features succeed [illegible]

steep, bluffy, banks, gravel beaches and short impassable tributary ravines. (Fig. 56.)

The southwest townships of the county are well drained by the several branches of Maple creek, Maple river in Cherokee county. In all parts of Buena Vista county where natural drainage has been less efficient, artificial channels have been constructed, their course dictated by the art of the civil engineer. Some of these form far-extended systems and drain whole townships at a time.

In general, in comparing the streams of the two counties here discussed it may be said that Mill creek, the Little Sioux, Brooke's creek and the several branches of the Coon river are all that they are largely by virtue of their relation to the Wisconsin drift; all the other drainage channels here mentioned are simple erosion valleys, ramifying into what was once a nearly level plain, the conduits of storm-water and this alone, in all their history. The first named channels are plainly different. Only casual observation suffices to show that they have been at some time flooded to the brim, that they have been again and again choked up with gravel, as often largely eroded and swept clean, and that they now accommodate streams insignificant in the presence of such effects.

STRATIGRAPHY.

The geological formations recognizable in Cherokee and Buena Vista counties are wholly of recent age. That is, they have been laid down in times recent and new as things geologic go. They consist in Iowa of sands, gravels, clays, or of a mixture of all three; often mingled together in any given locality, nevertheless not without a certain definite and easily ascertainable order when taken in wider and more comprehensive view.

These superficial strata are called collectively the Cenozoic, and those with which we have here to do are the latest of the Cenozoic. The following table shows the relation of these deposits to each other as these occur in northwestern Iowa.

TABLE OF FORMATIONS IN BUENA VISTA AND CHEROKEE COUNTIES.

GROUP.	SYSTEM.	SERIES.	STAGE.
Cenozoic.	Pleistocene.	Recent.	Alluvial.
		Glacial.	Wisconsin clays.
			Wisconsin gravels.
			Loess.
			Kansan.
			Pre-Kansan.

Pleistocene Deposits.

THE KANSAN DRIFT.

The Kansan drift as frequently defined in these reports is everywhere identified by the presence of a horizon of blue clay which appears to underlie all sorts of surface deposits, of whatever age, over almost the state entire. These blue clay deposits, when long exposed to the weather or to oxidation due to proximity to the present surface, become very much changed in appearance. They lose the blue tinge entirely and become brown or yellowish and where free from sand and gravel often show a peculiar jointed structure, as of crystalline origin, often with further decoloration or oxidation marking the seams. In this condition beds of Kansan clay may somewhat resemble loess, but are easily distinguished by lack of homogeneity, by the presence of drift pebbles, bowlders of various shapes and sizes distributed through the clay.

Now in the two counties here studied, as in all northwestern Iowa, there is no doubt of the universal presence of this Kansan till. Whatever the surface formation, whether drift, alluvial deposit, gravel, whatever it may be, the uniform report of those who dig wells, the country over, tells of the blue clay. The depth

at which the stratum occurs varies continually, but it is encountered invariably and everywhere if the drilling proceed to any considerable depth. In many places the depth, if we may trust reports, is not very great. At Storm lake, for instance, the bottom is said to be blue clay. South and west of the lake well reports give twenty to fifty feet as the usual horizon. In Brooke township, Buena Vista county, the brownish beds of joint clay are everywhere exposed by erosion along the short, steep-walled ravines. At Marcus in Cherokee county the blue clay is reported as at the surface, but only four miles north it was not encountered nearer than eighty feet from the black surface soil.

Immediately overlying the blue clay, constituting the commonly exposed drift of all Cherokee county and the western edge of Buena Vista, is a yellow but strongly calcareous till whose age and origin is still a matter of conjecture. The deposit is perhaps Kansan; it is certainly older than the Wisconsin, although at first sight closely resembling in appearance deposits elsewhere so described. It contains many of the elements of the Wisconsin; it is richly calcareous and contains limestone bowlders and pebbles in abundance. As ordinarily exposed it shows few signs of age, such as weathering or decomposition. In some localities, however, as along the south bank of the Little Sioux, it seems to be overlain by older material. It contains greenstone pebbles not a few, but carries also abundant fresh-looking granite bowlders, of small size as a rule, but of very varied composition. These, of course, are more plentifully displayed along the channels which have been more recently eroded. The whole body of this drift is of somewhat darker color than is the typical Wisconsin, and contains sand-bowlders here and there, and occasionally, low down, alternating beds of water-laid sand. South of Peterson the more coherent bowlder clay caps a bed of sand forty feet or more in thickness, and it appears elsewhere to overlie considerable beds of sand and silt as far south, at least, as Cherokee.* In the vicinity of Peterson and particularly northward from that point, up to the time of the drainage of the Wisconsin ice, the surface seems to have undergone only the slightest erosion. We have here a portion of the

* Iowa Geol. Surv., vol. XI, p 487.

flat prairie watershed left by the older drift. To this the regular processes of drainage which have so beautifully served the country to the south had not yet approached. At least the topography in this neighborhood is of the most recent type. Relying upon indications suggested by the topography chiefly, these deposits were mapped as Wisconsin in the report on Clay and O'Brien counties of two years ago. They may prove to be what has been described as earlier Wisconsin; they may be older. The same difficulty was encountered in Plymouth county, and for a more thorough presentation of the problem the reader is referred to the report on that county.* The problem will be referred to a little later on in the present report. Not until the whole drift of western Iowa from south to north is consecutively and continuously studied may we hope to see the stratigraphy of this part of Iowa definitely made out and accurately entered upon our maps.

As to pre-Kansan drift, we are also here not without abundant evidence. Reports of wells in various parts of both counties suggest, indicate assuredly, a forest-bed beneath the all-pervading blue clay. Not infrequently the well-digger encounters under the blue clay a "black muck" which gives up water indeed, but "stinking" water, unpotable of man or beast. The surprise of the ordinary land-owner under such circumstances is hardly to be wondered at. In some localities, as for instance southwest of Storm lake, a stratum of such decaying organic stuff several feet in thickness is reported, and the more shallow wells all over this section were rendered useless in this way. Fortunately, in most cases good water is obtainable by going deeper and casing out the waters of the muck horizon.

In no case is a solid or rocky horizon reported. However shallow or deep the well, the report of those who dig or bore is always the same; clay, gravel, sand, clay, "nigger-heads." All the drift below the muck beds, all below the blue clay must be reckoned pre-Kansan. How many successive drift formations this term pre-Kansan may include who may now declare? From the nature of the case less is known of their character and extent, although they have been reported from different places in western

* Iowa Geol. Surv., vol. VIII, pp. 335-351.

Iowa and in some places at least are easily accessible for investigation.

All that we know of the pre-Kansan in northwestern Iowa indicates its surprising depth. In the report made last year concerning O'Brien county reference was made to two very deep wells, wholly in the drift, one in Omega and one in Caledonia township. The latter is reported as more than one thousand feet deep. We have now confirmation for the depth at the latter point. At Marcus, immediately to the south of the Caledonia well and at no great distance, seven or eight miles, the Illinois Central railway undertook recently the drilling of a well. By the courtesy of Mr. W. J. Harnahan we have the record of the boring made:

"From the surface to thirty feet in depth, blue clay.

From thirty to 560 feet, yellow clay mixed with bowlders.

From 560 to 680 feet in depth, red clay containing numerous bowlders.

At the latter depth the well was abandoned. No solid rock was encountered, but the numerous lot of large bowlders and "nigger-heads" made it almost impossible to get the hole down."

Here we have the pre-Kansan for 530 feet and below that easily identifiable, by color at least, another stratum 120 feet in thickness and still no rock in place! The thinness of the Kansan is surprising. It would seem as if all the oxidized upper portions of that old formation had been in this locality swept away, perhaps by the erosion of the Wisconsin times. A little farther to the north, however, the blue clay is covered by the usual deposits of loess, yellow drift, gravel and sand very much as in the southern parts of Cherokee county. Evidently any coal that may exist beneath Marcus is pretty deep down.

There seems to be plainly enough a vast body of ancient drift extending from northwest to southeast across several counties here. This drift formed a watershed in Kansan times, forms a watershed still, despite all the erosion that has succeeded its deposit, despite the fact that since its deposit another glacial epoch has come and gone.

THE LOESS.

The peculiar fine yellow clay known as loess is a characteristic surface deposit over the larger part of Cherokee county and over

most of the western townships of Buena Vista county. In Cherokee county all the country south and west of Mill creek is loess-covered. North and east of this stream, loess is doubtless to be found, but everything is obscured by the more or less abundant and extensive deposits of overwash Wisconsin gravel. The transition from one surface to the other is often abrupt. Thus if the traveler going south crosses the bridge near schoolhouse No. 5, Cherokee township, there is no loess north of the bridge, but on the south side of the creek the loess appears abundantly along the highway and so on west from the schoolhouse named to Cleghorn. West from Cleghorn there is no trace of the later drift. Marcus is in sight on the high table-land or divide already mentioned, but the drainage is everywhere good: there are no swamps and bowlders. Immediately south of schoolhouse No. 1 in Anthony township, and one mile south of the Cleghorn road, there may be seen a fine exposure of typical loess, six or eight feet in thickness. It appears to rest immediately upon a bed of gravel. Over all this part of the country there is scarce a bowlder to be found: not one in sight as the traveler passes along the highway. A few small granite blocks are said to occur, but none attract attention on hill or in valley. Those used by the farmers for foundation stones are hauled from the valley of Mill creek. We are beyond all trace of the influence of the Wisconsin drift in this direction. At and around Marcus the subsoil is everywhere loess, though often rather thin, but thickening to the north. Wells often do not reach the blue clay but show abundant water at from ten to thirty feet. North of Marcus a cistern in process of excavation showed loess six feet, sand, five; no gravel. The excavator and the owner agreed that twenty feet of sand often lay above the blue clay. This will account for the success of the shallow wells above referred to. There are evidences of loess in O'Brien county as far north as Paullina, but in O'Brien county the formation occurs in patches; it nowhere forms a mantle covering the whole country as in southern and western Cherokee county.

THE WISCONSIN GRAVELS.

These deposits as usual occupy the valleys, especially the valleys of all streams leading away from the margin of the Wisconsin drift. They are not conspicuous in Buena Vista county, but in Cherokee county, along the Little Sioux and in the valley of Mill creek they are everywhere in evidence. Indeed, nearly all the northeastern part of Cherokee county is heavily charged with gravel deposits. Mill creek, from a point nearly north of Meriden to its union with the Little Sioux, presents the appearance of having been at one time nearly if not altogether choked with gravel. This stream in this respect is in singular contrast with the streams on the western side of Cherokee county. All the tributaries of Mill creek, and these are generally from the north, appear like Alpine channels; they are literally paved with bowlders. In section 4 of Cherokee township on the level of the flood-plain of the creek there is a curious gravel mound, probably a residuum of post-glacial erosion. Brooke's creek shows some evidence of this same overwash gravel but nothing like as much as might have been expected. There seems never to have been very much current northward in that part of the stream now named Brooke's creek. At the same time, the channels leading into Brooke's creek and Fox creek are paved with bowlders much as in the vicinage of Mill creek. Most of these, however, seem to have come from the eroded drift of the locality.

There is a very heavy deposit of drift at Sioux Rapids, high above the course of the present stream; but more remarkable still, there is a moderately large, well defined gravel mound, not stratified, so far as could be ascertained, just north of Larrabee, its materials used now constantly for the improvement of the streets of that village. The Sioux Rapids gravel may be esteemed part of the overwash of the great Wisconsin ice margin which lay in the upper part of the town; but the Larrabee mound may mean something more. It is not isolated, but forms part of a continuous series of such deposits extending from Sibley south and east, including the gravel pit at Sheldon and similar deposits about Calumet. All these taken together and studied in connection with the peculiar topography of eastern O'Brien county may indicate that the Wisconsin ice did after all, transiently at least,

go over the great divide in this particular region. However, these gravel deposits form only one of the many indications that all this part of the country has been profoundly modified by the Wisconsin drift sheet, even if it be finally concluded that the ice itself never passed over it. This phase of the subject will be considered later on. It remains only here to say that these extra-limital gravels, if so they may now be termed, possess some peculiarities not commonly noted in connection with mounds that are plainly intra-morainic. The Sheldon gravel, for instance, is plainly covered by a deposit that may be fairly denominated loess, whatever its source. The gravel contains a goodly number of rotten bowlders and, as heretofore described, the lower layers have become silicified, or rather solidified, by percolations from above. Similar peculiarities are noticeable in all the localities specified. Even south of Larrabee, in section 1 of Cherokee township, identically the same solidified layer may be found near the bottom of a deposit of gravel, showing identity of composition and history. It is possible, as above suggested, that all this is but an overwash dating from the ultimate retirement of the Wisconsin ice, but the situation suggests the need of more exhaustive inquiry.

However all this may be, there are to be found, stretching entirely across Buena Vista county from north to south, and almost across it from east to west, mounds of gravel of no uncertain meaning. These mark well for us the westward limits of the latest drift. They are morainic; they form here the Altamont or marginal deposit of the Wisconsin ice. Many of these mounds or hillocks are merely capped with gravel, some show at the surface little or none; most are gravel and sand throughout. In this county they are generally low, often hardly noticeable to the untrained eye and are in general, save for their geologic interest, wholly insignificant.

THE WISCONSIN CLAYS.

Typical Wisconsin drift is exposed only here and there in central and eastern Buena Vista county. For the most part the surface is so very level that erosional or other cuttings are few. Along the banks of the Little Sioux river, as near Sioux Rapids,

are beautiful drift exposures afforded by railway cuts and recent erosion; but as has been already indicated this body of drift is certainly older than the ordinary Wisconsin till, older than the drift contained within the Altamont moraine. Nevertheless, there is no doubt but that a thin sheet of typical Wisconsin clay-drift underlies as subsoil nearly all of the eastern half of Buena Vista county. Opportunities for observation are not many, owing to the level topography, wells being almost the only recourse. Cuts made in draining or shaping the highways often show nothing but a deep black soil, or, where a mound or morainic ridge must needs be cleft, the exposure shows little but gravel. Contact between the older and later drift, except where the latter was represented by sand or gravel, was nowhere observed.

ALLUVIAL DEPOSITS.

Alluvial deposits in Buena Vista county are limited almost entirely to the immediate borders of the Little Sioux. At Sioux Rapids and thence west to and including the mouth of Brooke's creek, there are found splendid alluvial bottom lands with deep warm soil, the most fertile in the county. The valleys of the several divisions of Maple river show similar beautiful alluvial meadows, sometimes a mile and more in width. Similar soils, though nothing like so deep, cover more or less completely the widespread gravel trains that stretch southward and westward from Cherokee, along the banks of the Little Sioux. Such soil conditions are to be especially noted in the vicinity of Quimby. The Little Sioux alluvium is, however, a very different thing from that of the Maple system of streams. The latter is the result of slow erosion with gradual accumulation from the rich surface of the surrounding slopes. In consequence the erosion of the present stream exposes a black soil, many feet in thickness, with only here and there a trace of sand and gravel. Along the Sioux on the contrary, on account of the entirely different history already sketched, the present erosion makes havoc of the comparatively thin veneer of rich soil and exposes the subsoil of the gravel train or sweeps it down to hamper the meadows and lower-lying fields.

THE MARGIN OF THE WISCONSIN DRIFT.

In all the study of these northwestern counties of Iowa one object of the Survey, kept continually in mind, has been the determination in this direction of the western limits of what has all along been designated as the Wisconsin drift. The fact of the identity of this deposit within its own limits, is almost everywhere easily discoverable; but when we come to define the deposit at its margin and in respect to other and older formations, not as it might appear in some clean vertical section, but as it comes to view spread out upon the surface of the ground, we are confronted by difficulties not a few.

In the first place, the drift itself near its margin is not always typical in constitution or character. The till which it overlies may perchance contain many of the same elements, derived by an earlier ice-flood from identical sources, and so, except as modified by time, present much the same appearance. Now the time modifications, weathering, oxidation, etc., are always in the older drift shown at their best, of course, nearest to the surface. But by the very conditions of the problem the surface is just that part of the older drift most likely to be altered or even entirely removed, especially at a glacial margin at the time of recession, when everything is more or less completely swept by marginal drainage floods. A clean section of undisturbed, indisputable superposition is at the very margin of an overlying sheet scarcely to be expected. We should the rather be prepared, as far as the constitution of exposed material is concerned, to find a commingling of elements old and new, or the deposit of the latter drift upon beds also fresh in appearance, because in large measure deprived, by the very on-coming of the later drift, of those superficial characteristics, time-developed and distinctive. Of course, in numberless instances the old surface is yet perfectly identifiable, but such instances are to be looked for well within the margin of the later sheet.

Furthermore, the marginal material, well washed by the waters of the melting ice, is apt to consist largely of sand and gravel, spread sometimes far beyond the limit of actual ice action and as such often hardly distinguishable from other gravel deposits having a different origin and a different history.

As far as composition is concerned, we are required in the present problem to distinguish between the Wisconsin and an older body of drift or till. The Wisconsin and Kansan have already been contrasted in an earlier volume of the present series.* At the drift margin, as suggested, all these distinctions are apt to be very much obscured.

In the second place in our effort to delimit a glacial sheet such as the Wisconsin we must always be guided to a very considerable extent by purely surface indications, by the character of the surface soil, the presence or absence of surface bowlders, and above all by the configuration of the surface as expressed in general topography. In Iowa, almost without exception, the older drift sheets are covered by a mantle of well defined loess; the Wisconsin is so far supposed to be without loess.* It is generally conceded that where other indications are lacking the presence of a deposit of loess may be taken as a mark of the older drift. Unfortunately the test is not infallible. Near the borders of the Wisconsin the loess seems to have been sometimes entirely swept away or at least so confused with outward material as to render its identification less positive. Thus the loess is plainly in evidence in Buena Vista county, close up to the borders of the later drift, but in the ultra-morainic portions of Clay and O'Brien counties, far out from the definitely marked drift margin, no loess was discovered.

Again the surface of the older drift is practically destitute of bowlders; not that there are not plenty of Kansan bowlders, but that these are not commonly found at or on the surface. In boring wells they are encountered all too often, and are brought to light everywhere along the water courses by the ordinary processes of present erosion. The famous Pilot Rock in Cherokee county is a magnificent Sioux quartzite bowlder, (Fig. 57.) exposed by the erosion that has gone on before it and around it especially since the days of the Wisconsin drift and probably long before. All the valleys leading into the Little Sioux near its exit from Buena Vista county are crowded with bowlders, probably most of them released by recent rapid erosion, although

* Iowa Geol Surv., vol. VI, p. 439.
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FIG. 57. Pilot rock, a Sioux quartzite bowlder, four miles south of Cherokee, Iowa.

some of them may be of Wisconsin origin and owe their present position to blocks of drifting Wisconsin ice.

But the most patent distinction between earlier and later glacial deposits is found in the topography of the deposits themselves. This has often been pointed out and is referred to here only because necessary to the elucidation of some peculiar features in the present problem. For instance, in attempting to delimit anywhere the Wisconsin lobe by the topography we may generally consider that we have passed the border when we leave evidence of recent erosion and come out upon that which is plainly ancient and exhibits the results of long subjection to the ordinary destructive influences of the weather. Imperfect drainage and erosion resulting in short deep ravines indicate, in so far, newness and generally in northwestern Iowa are marks of the Wisconsin drift.

Again the cessation of the ice advance in the path of any glacier is marked by the deposition which always takes place in the most definite and characteristic, though often irregular fashion. Piles of sand and gravel occur as mounds and hillocks, anywhere and everywhere. These as we know are called morainic hills:

taken altogether they constitute the moraine, and, when laid down in the field of ultimate ice-extension or occupancy, they form the Altamont moraine. Other things being equal, the outer limits of the glacial deposit are marked by the course of the Altamont moraine.

Now all these characteristics by which the boundaries of an ice sheet may usually be discerned are subject in the very nature of the case to modifications affecting every one of the details indicated. Some of these possibilities have been touched upon already in the pages immediately preceding. For instance, in the matter of surface deposits; if the landscape reached by the invading ice, should, notwithstanding age, have remained after all flat or poorly drained, it may be covered on the glacial retreat by all sorts of new material in the form of overwash, or it may remain level and be cut in every direction by new drainage channels and so simulate in all respects a typical youthful topography.

Again the effect of the presence of the glacier on streams and valleys accurrent is most pronounced. The tendency may be easily imagined; all streams and valleys accurrent will be more or less completely dammed up, their channels partly filled or converted into marshes, lakes and swamps: so that such a valley ceases entirely to form part of the drainage system of the country, or even cuts a new channel parallel to the glacier's front, and finally persists as a new stream, losing for the student almost all diagnostic value, though demanding explanation.

On abcurrent channels the effect is of course quite the reverse. Such conduits will be called upon suddenly to carry far more than the usual quota of waters. They will become widely and deeply eroded; new channels, even here also, may be cut through where there were none before and all old drift material and alluvium be re-sorted and mingled with the new: as the current slackens in volume and speed the wide new-washed channel may be in part filled up, only again to suffer erosion with the subsequent action of the persistent stream whether large or small, and, as before, all the most vivid peculiarities of recent erosion may be found associated with drift far older than the topography would at first imply.

All these conditions are abundantly illustrated by the concrete example before us. We may see them all as we attempt to trace the Altamont moraine from the point where it emerges from the northern townships of Carroll county.* The accompanying map shows an irregular border trending north and west to the northern line of the state.

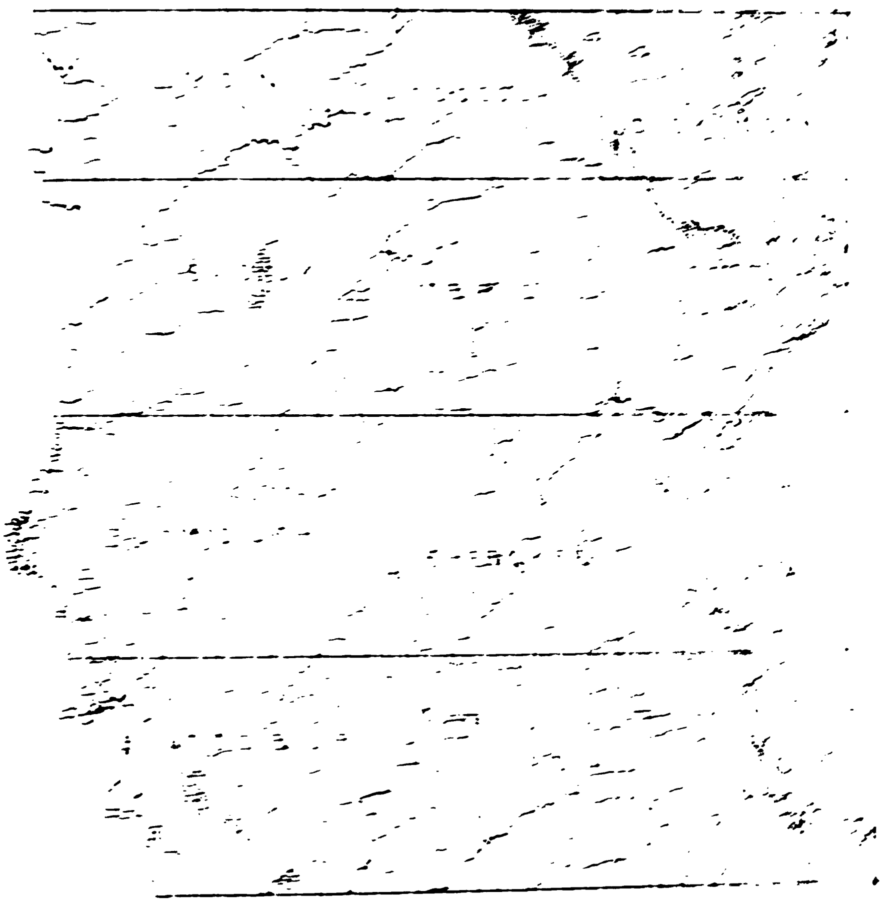

FIG. [illegible] [illegible]

The array [illegible] broken, sometimes fails [illegible] generally be [illegible] to follow along the [illegible]

* [illegible]

It has not been found practicable to show on the map the width of the conformation since the range of mounds and kames in this region is nowhere simple; rather is the Altamont here bound back to very numerous secondary or recessional moraines marking various and repeated oscillations incident upon the close of the period. However the moraine is sometimes very narrow indeed, not more than a mile or two in width; then again it may effect more or less completely a township, a county, or more. The map then indicates the outer or distal limits only; for further details the reader is referred to the particular maps of the several counties forming part in the general problem.

Leaving Carroll county at a point nearly south of Carnarvon, the Altamont may be traced through Carnarvon to Lake View. Wall lake lies in the very margin of the morainic wall, but terminates southwesterly in wide deposits of gravel, which have to a large extent filled up an ancient river channel, apparently a part of that which is now the Boyer, probably the principal stream of an ancient Boyer system. The entire upper portion of this stream with all its eastern tributaries was obliterated by the Wisconsin ice. During the life of the glacial sheet a new Boyer was formed, namely, the present stream, above the point near where the Northwestern railway crosses the river west of the town of Wall Lake. It will be noticed that the present river here debouches into the old valley. The present river was in large part, at least, the marginal drainage channel, while that part of the original Boyer channel which lies between the present Wall lake and the point of debouchment specified was practically abandoned, if not wholly so. With the approach of the ice from the north the old river seems to have continued for some time efficient; its old channel in the abandoned portion being filled with gravel as of a gradually failing stream, like the Platte, for instance; but at the final retreat no permanent stream remained, however small, to open up a new channel and so occupy in this particular place the old river bed. Wall lake lay as a pool in the part nearest the moraine, just in the moraine, in fact, prevented by the accumulated gravel, and by nothing more substantial, from contributing even so much as its overflow to the current of the Boyer river; while Indian creek and Coon river,

BY

T.H.MACBRIDE
1902.

Scale $\frac{1}{125000}$

4 5 Miles.

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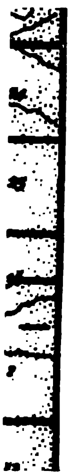

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Scale $\frac{1}{125000}$

5 Miles

Iowa and in some places at least are easily accessible for investigation.

All that we know of the pre-Kansan in northwestern Iowa indicates its surprising depth. In the report made last year concerning O'Brien county reference was made to two very deep wells, wholly in the drift, one in Omega and one in Caledonia township. The latter is reported as more than one thousand feet deep. We have now confirmation for the depth at the latter point. At Marcus, immediately to the south of the Caledonia well and at no great distance, seven or eight miles, the Illinois Central railway undertook recently the drilling of a well. By the courtesy of Mr. W. J. Harnahan we have the record of the boring made:

"From the surface to thirty feet in depth, blue clay.

From thirty to 560 feet, yellow clay mixed with bowlders.

From 560 to 680 feet in depth, red clay containing numerous bowlders.

At the latter depth the well was abandoned. No solid rock was encountered, but the numerous lot of large bowlders and "nigger-heads" made it almost impossible to get the hole down."

Here we have the pre-Kansan for 530 feet and below that easily identifiable, by color at least, another stratum 120 feet in thickness and still no rock in place! The thinness of the Kansan is surprising. It would seem as if all the oxidized upper portions of that old formation had been in this locality swept away, perhaps by the erosion of the Wisconsin times. A little farther to the north, however, the blue clay is covered by the usual deposits of loess, yellow drift, gravel and sand very much as in the southern parts of Cherokee county. Evidently any coal that may exist beneath Marcus is pretty deep down.

There seems to be plainly enough a vast body of ancient drift extending from northwest to southeast across several counties here. This drift formed a watershed in Kansan times, forms a watershed still, despite all the erosion that has succeeded its deposit, despite the fact that since its deposit another glacial epoch has come and gone.

THE LOESS.

The peculiar fine yellow clay known as loess is a characteristic surface deposit over the larger part of Cherokee county and over

most of the western townships of Buena Vista county. In Cherokee county all the country south and west of Mill creek is loess-covered. North and east of this stream, loess is doubtless to be found, but everything is obscured by the more or less abundant and extensive deposits of overwash Wisconsin gravel. The transition from one surface to the other is often abrupt. Thus if the traveler going south crosses the bridge near schoolhouse No. 5, Cherokee township, there is no loess north of the bridge, but on the south side of the creek the loess appears abundantly along the highway and so on west from the schoolhouse named to Cleghorn. West from Cleghorn there is no trace of the later drift. Marcus is in sight on the high table-land or divide already mentioned, but the drainage is everywhere good; there are no swamps and bowlders. Immediately south of schoolhouse No. 1 in Anthony township, and one mile south of the Cleghorn road, there may be seen a fine exposure of typical loess, six or eight feet in thickness. It appears to rest immediately upon a bed of gravel. Over all this part of the country there is scarce a bowlder to be found; not one in sight as the traveler passes along the highway. A few small granite blocks are said to occur, but none attract attention on hill or in valley. Those used by the farmers for foundation stones are hauled from the valley of Mill creek. We are beyond all trace of the influence of the Wisconsin drift in this direction. At and around Marcus the subsoil is everywhere loess, though often rather thin, but thickening to the north. Wells often do not reach the blue clay but show abundant water at from ten to thirty feet. North of Marcus a cistern in process of excavation showed loess six feet, sand, five; no gravel. The excavator and the owner agreed that twenty feet of sand often lay above the blue clay. This will account for the success of the shallow wells above referred to. There are evidences of loess in O'Brien county as far north as Paulina, but in O'Brien county the formation occurs in patches; it nowhere forms a mantle covering the whole country as in southern and western Cherokee county.

THE WISCONSIN GRAVELS.

These deposits as usual occupy the valleys, especially the valleys of all streams leading away from the margin of the Wisconsin drift. They are not conspicuous in Buena Vista county, but in Cherokee county, along the Little Sioux and in the valley of Mill creek they are everywhere in evidence. Indeed, nearly all the northeastern part of Cherokee county is heavily charged with gravel deposits. Mill creek, from a point nearly north of Meriden to its union with the Little Sioux, presents the appearance of having been at one time nearly if not altogether choked with gravel. This stream in this respect is in singular contrast with the streams on the western side of Cherokee county. All the tributaries of Mill creek, and these are generally from the north, appear like Alpine channels; they are literally paved with bowlders. In section 4 of Cherokee township on the level of the flood-plain of the creek there is a curious gravel mound, probably a residuum of post-glacial erosion. Brooke's creek shows some evidence of this same overwash gravel but nothing like as much as might have been expected. There seems never to have been very much current northward in that part of the stream now named Brooke's creek. At the same time, the channels leading into Brooke's creek and Fox creek are paved with bowlders much as in the vicinage of Mill creek. Most of these, however, seem to have come from the eroded drift of the locality.

There is a very heavy deposit of drift at Sioux Rapids, high above the course of the present stream; but more remarkable still, there is a moderately large, well defined gravel mound, not stratified, so far as could be ascertained, just north of Larrabee, its materials used now constantly for the improvement of the streets of that village. The Sioux Rapids gravel may be esteemed part of the overwash of the great Wisconsin ice margin which lay in the upper part of the town; but the Larrabee mound may mean something more. It is not isolated, but forms part of a continuous series of such deposits extending from Sibley south and east, including the gravel pit at Sheldon and similar deposits about Calumet. All these taken together and studied in connection with the peculiar topography of eastern O'Brien county may indicate that the Wisconsin ice did after all, transiently at least,

go over the great divide in this particular region. However, these gravel deposits form only one of the many indications that all this part of the country has been profoundly modified by the Wisconsin drift sheet, even if it be finally concluded that the ice itself never passed over it. This phase of the subject will be considered later on. It remains only here to say that these extra-limital gravels, if so they may now be termed, possess some peculiarities not commonly noted in connection with mounds that are plainly intra-morainic. The Sheldon gravel, for instance, is plainly covered by a deposit that may be fairly denominated loess, whatever its source. The gravel contains a goodly number of rotten bowlders and, as heretofore described, the lower layers have become silicified, or rather solidified, by percolations from above. Similar peculiarities are noticeable in all the localities specified. Even south of Larrabee, in section 1 of Cherokee township, identically the same solidified layer may be found near the bottom of a deposit of gravel, showing identity of composition and history. It is possible, as above suggested, that all this is but an overwash dating from the ultimate retirement of the Wisconsin ice, but the situation suggests the need of more exhaustive inquiry.

However all this may be, there are to be found, stretching entirely across Buena Vista county from north to south, and almost across it from east to west, mounds of gravel of no uncertain meaning. These mark well for us the westward limits of the latest drift. They are morainic; they form here the Altamont or marginal deposit of the Wisconsin ice. Many of these mounds or hillocks are merely capped with gravel, some show at the surface little or none; most are gravel and sand throughout. In this county they are generally low, often hardly noticeable to the untrained eye and are in general, save for their geologic interest, wholly insignificant.

THE WISCONSIN CLAYS.

Typical Wisconsin drift is exposed only here and there in central and eastern Buena Vista county. For the most part the surface is so very level that erosional or other cuttings are few. Along the banks of the Little Sioux river, as near Sioux Rapids,

are beautiful drift exposures afforded by railway cuts and recent erosion; but as has been already indicated this body of drift is certainly older than the ordinary Wisconsin till, older than the drift contained within the Altamont moraine. Nevertheless, there is no doubt but that a thin sheet of typical Wisconsin clay-drift underlies as subsoil nearly all of the eastern half of Buena Vista county. Opportunities for observation are not many, owing to the level topography, wells being almost the only recourse. Cuts made in draining or shaping the highways often show nothing but a deep black soil, or, where a mound or morainic ridge must needs be cleft, the exposure shows little but gravel. Contact between the older and later drift, except where the latter was represented by sand or gravel, was nowhere observed.

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In the second place in our effort to delimit a glacial sheet such as the Wisconsin we must always be guided to a very considerable extent by purely surface indications, by the character of the surface soil, the presence or absence of surface bowlders, and above all by the configuration of the surface as expressed in general topography. In Iowa, almost without exception, the older drift sheets are covered by a mantle of well defined loess; the Wisconsin is so far supposed to be without loess.* It is generally conceded that where other indications are lacking the presence of a deposit of loess may be taken as a mark of the older drift. Unfortunately the test is not infallible. Near the borders of the Wisconsin the loess seems to have been sometimes entirely swept away or at least so confused with outward material as to render its identification less positive. Thus the loess is plainly in evidence in Buena Vista county, close up to the borders of the later drift, but in the ultra-morainic portions of Clay and O'Brien counties, far out from the definitely marked drift margin, no loess was discovered.

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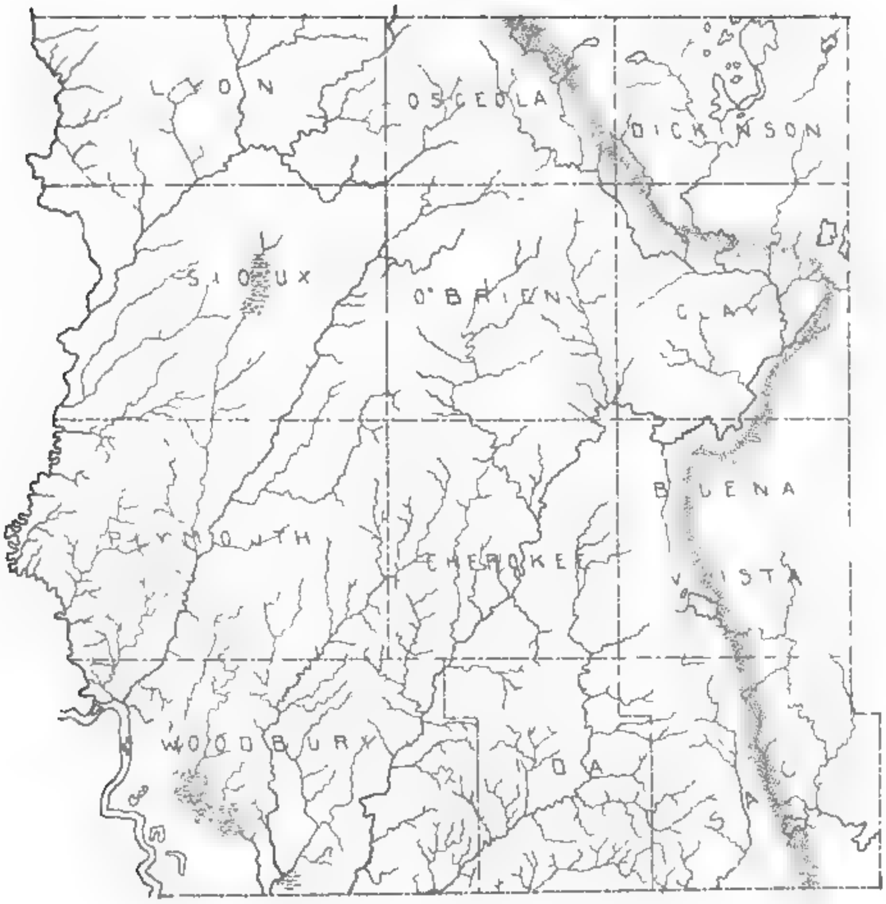

FIG. 58. Map showing approximately the location of the Wisconsin Altamont moraine in Northwestern Iowa, in the light of present knowledge.
—*By T. H. Macbride.*

The array of hillocks thus indicated is often very much broken, sometimes fails for a few miles altogether, but may generally be kept in easy vision all the way by the student who attempts to follow along the highways the course of the moraine.

* Iowa Geol. Surv., vol. IX., pp. 57-60.

It has not been found practicable to show on the map the width of the conformation since the range of mounds and kames in this region is nowhere simple; rather is the Altamont here bound back to very numerous secondary or recessional moraines marking various and repeated oscillations incident upon the close of the period. However the moraine is sometimes very narrow indeed, not more than a mile or two in width; then again it may effect more or less completely a township, a county, or more. The map then indicates the outer or distal limits only; for further details the reader is referred to the particular maps of the several counties forming part in the general problem.

Leaving Carroll county at a point nearly south of Carnarvon, the Altamont may be traced through Carnarvon to Lake View. Wall lake lies in the very margin of the morainic wall, but terminates southwesterly in wide deposits of gravel, which have to a large extent filled up an ancient river channel, apparently a part of that which is now the Boyer, probably the principal stream of an ancient Boyer system. The entire upper portion of this stream with all its eastern tributaries was obliterated by the Wisconsin ice. During the life of the glacial sheet a new Boyer was formed, namely, the present stream, above the point near where the Northwestern railway crosses the river west of the town of Wall Lake. It will be noticed that the present river here debouches into the old valley. The present river was in large part, at least, the marginal drainage channel, while that part of the original Boyer channel which lies between the present Wall lake and the point of debouchment specified was practically abandoned, if not wholly so. With the approach of the ice from the north the old river seems to have continued for some time efficient; its old channel in the abandoned portion being filled with gravel as of a gradually failing stream, like the Platte, for instance; but at the final retreat no permanent stream remained, however small, to open up a new channel and so occupy in this particular place the old river bed. Wall lake lay as a pool in the part nearest the moraine, just in the moraine, in fact, prevented by the accumulated gravel, and by nothing more substantial, from contributing even so much as its overflow to the current of the Boyer river; while Indian creek and Coon river,

Tp. 92. N

BY

T.H.MACBRIDE
1902.

Scale $\frac{1}{125000}$

5 Miles.

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Miles

just inside the same moraine, effected the drainage as well as might be of that particular region which had in pre-Wisconsin times been the gathering ground of probably the main stream of what is called the Boyer. These last named streams still continue in their own crooked ways, while the divide that separates Wall lake and its marshes from the present valley of the Boyer cannot be more than a dozen feet, possibly not half so much; it is not perceptible to one passing over the ground.

From Wall lake the Altamont bends northwest and crosses the township line road at a point about six miles north of the village of Wall Lake; it then continues almost due north at a distance of from one-half a mile to one mile west of the township line road just mentioned, quite or almost to the southern limits of Delaware township. Here the border bends west to include Round lake, thence almost due north to the village of Northam on the line of the Chicago, Milwaukee and Saint Paul railway which here follows for some distance the outer margin of the moraine. Northam is in a notch in the moraine. From Northam the hills trend north and then west. The ice sheet appears to have obliterated entirely on the east the drainage channel of which Storm lake and its accompanying marsh appear to be a residual part. Indeed it is not impossible that Storm lake and its accompanying marshes may even form part of the same old-time drainage system as that represented by Wall lake farther south. At any rate Storm lake and its northwestward extension, though offering typical Wisconsin topography, probably occupy a pre-Wisconsin valley and lie outside the Altamont moraine. The ice margin would appear to have reached the lake on the east and northeast but not on the west. Here is, however, a problem for closer investigation than was possible in the present course of the survey. Some local student will find this a fruitful field for further inquiry.

North of Storm lake the moraine trends northwest by west. It is encountered by anyone who drives northward along the highway passing through the center of Washington township. It is first met at the corner of sections 21 and 27. Thence the moraine follows the general course of Brooke's creek. For a couple of miles the newer drift here also acted as a dam and we have a series

of marshes extending half way to Alta. These marshes continue for several miles through Washington township and for some distance in Elk, indicating the stoppage of the original drainage here. They are all now tributary to Brooke's creek, though still much in need of assistance in the way of tiling and ditching. From Elk township north Brooke's creek is well defined, seems to have formed for a short distance, and comparatively short time, the drainage channel for the margin of the ice; and the limits of the moraine, here trending north and south, are determined by Brooke's valley, though less perfectly indicated by the hills themselves everywhere much affected by erosion. Indeed the morainic hills of the northern part of Buena Vista county extend in low billowy ranges in the general direction of east and west, and the Altamont moraine often fades out into a mere deposit of sand or gravel modifying the surface soil. This is plainly the case immediately south of Linn Grove. The moraine is within a few rods of the village but so spread out as to be hardly discernable, and yet identifiable in the topography and by the constitution of the surface soil.

From Linn Grove east the moraine follows the general course of the Little Sioux. The ice probably reached the present course of the stream in many localities but the evidence of this approach has been largely swept away by erosion; thus Soldier creek, at one time in its turn part of the marginal drainage system, has greatly affected the original form of the country along the south bank of the river. Nevertheless, all the way from Linn Grove to Sioux Rapids there are curious indications of the obliteration of an older topography. Thus in the southeast quarter of section 10 in Barnes township, within half a mile of the river, we have a marsh that can be explained on no other hypothesis. At the point where the Minneapolis railway is crossed by a high bridge, northeast quarter of section 14, there is evidence of the filling up of an earlier drainage channel, not very large, it is true, but patent. In many localities the drainage of the surface is yet *away from the river,* in fact in the original direction as will be explained later.

At Sioux Rapids the morainic deposits occupy the upper portion of the city. Here is to be referred the deposits and gravel

at the schoolhouse and at the city water tower, but not those before mentioned as overwash, and now used by the city as a gravel pit. From Sioux Rapids the margin of the morainic deposits may be traced eastward toward Marathon and again north at a little distance generally from the river but once more forming its southern bank through the northern half of Herdland township in Clay county, and especially at and about Gillett's Grove. From this point the moraine bends off to the northeast again, toward the center of Logan township, thence northward, a little east of the center of the township, then north again and finally west and northwest through the town of Dickens, thence almost west to a point north of Everly. From this point the border follows almost exactly the course of the Ocheyedan river, emerging from Osceola county and leaving Iowa at a point just east of the station Biglow in Minnesota. The details for Dickinson and Osceola counties have been already somewhat discussed in these reports* and may be more accurately presented in a special map hereafter.

The Little Sioux river, with the Ocheyedan as its western tributary, will thus appear to have been determined in its course from the state line almost to Peterson by the margin of the Wisconsin ice. Indeed, there is no doubt that the stream between the limits named acted as drainage channel probably for a long time, as long as the ice lay in the vicinity. A glance at the map is all that is needed to show to any observer that in some way the course of the drainage in this part of Iowa has been strangely changed. The high plateau followed by the Chicago, Rock Island and Pacific railway from Webb to Sibley, seems to have been without doubt a pre-Wisconsin divide, the very crown of the ancient drift and yet undrained, or at least but little eroded by the drainage channels which led off east and west, perhaps chiefly east. It may be, for instance, that the Little Ocheyedan represents in part at least one of these older streams, but the remarkable out-thrust of a lobe of ice westward nearly across Buena Vista county changed the whole face of the country. A study of the topography of O'Brien county led the present writer to believe that the larger part of that county had been covered by the Wisconsin ice, though irregularly and by a sheet that left

* Iowa Geol. Surv., vol. X, pp. 189-239.

deposits of very moderate thickness and was soon withdrawn.*

We are now in position to sketch the history of present topography of all the northwest portion of our state. The invasion of the Wisconsin ice was from the north with a distinct trend toward the southeast. This was probably occasioned by the existing configuration of the country. There existed a well-perfected drainage system tributary to the Mississippi river, probably by way of the Des Moines valley much as now. As the ice reached our northern frontier north of the counties we have been studying, it at first made use of the existing stream channels, both west and east. The outwash from the glacier's front went over the Rock river system of streams. This is abundantly evidenced by the omnipresent deposits of Wisconsin gravels all the way down the Rock river and even yet discoverable far above the level of the present flood plain, as in the vicinity of Rock Valley in Sioux county. The streams on the east side of the divide were obliterated as the ice progressed and the entire drainage thrown more and more westward against the divide as against a wall. This resulted in the present Ocheyedan river with its high erosion wall on the western or southwestern bank and the deposits of gravel at high levels and far out of the course of present floods as at Allendorf, for instance. The upper course of the Little Sioux seems to have been used for a while but eventually cut off below or southwardly by some westward thrust of the ice across its course. When the ice front rested but little north of Spencer, or possibly at Spencer, the Ocheyedan still conveyed away its waters, passing the present site of the town of Dickens and so on eastward probably to what was then the Des Moines. From a point about half-way between Dickens and Ruthven the ice began to move directly south and then a few miles to the west, throwing the river by a sharp flexure first to the west and then south. This movement cut the river off entirely from its old eastern conjunction with the Des Moines and shunted it southward, perhaps into a channel at that time continuous with what we now recognize as the Boyer, from the town of Wall Lake south: so that the Ocheyedan for a while actually drained into the Missouri instead of the Mississippi and by the way of the

* Compare vol. XI, p. 486. The entire report on O'Brien county was left uncertain and tentative for lack of information as to what lay south. See vol. XI, p. 482.

Boyer. As we shall see, it never got into the Mississippi again. At this time the river occupied as part of its channel in Clay county the great valley in Logan township of Clay county now called Elk valley and occupied by the insignificant Elk creek. Later by a westward thrust of the ice this channel was also cut off, the glacier approaching Gillets Grove. The damming of the water by this move seems to have thrown the river over a portion of the divide hitherto untouched, namely that part immediately south of Dickens, so that the river here assumed its present channel. From Gillets Grove the drainage seems to have still passed for some time on south, past Webb and Marathon, until at length the ice moved west once more, this time to Brooke's creek, obliterating its own drainage channel southward and sending the waters of the river over the divide by way of Sioux Rapids and Linn Grove into what was probably already Brooke's creek, pouring into the Waterman just beyond Peterson and so occupying the channel of that stream south through Cherokee county.

Such a history as this accounts for a great many of the peculiar features of the region described; perhaps for nearly or quite all of them. It will be noted that the ice in accomplishing this singular deflection of the river, now called the Little Sioux, but which is really more exactly as we see the Ocheyedan, occupied continually strategic points. It does not always by its moraine touch the channel of the present stream, but meets it only at those points essential to throw it in the direction it has finally assumed. Thus the moraine reaches the river at Ocheyedan, at Spencer, at Gillets Grove, and again from Sioux Rapids to Linn Grove, and so accomplishes the whole movement. If it be objected that the terrene about Marathon and east of the river generally is lower than the table-land about Peterson, we have only to reflect that the change in the course of the river was not effected by the terrene but by the ice-front itself, and that the channel was cut to its present depth, or deeper, while the ice was still the dominant factor in the topography. The lowlands about Webb and south and the present course of the intra-morainic Coon river indicate the probable course of the drainage before the westward out-push, and are low for that very reason. Under some such hypothesis as that herein set forth we may reasonably

explain the peculiar topographic and other surface features of western Clay and southern O'Brien counties. In the successive damming up of the river, first in the vicinity of Ruthven, and then further south at Gillet's Grove and at Sioux Rapids, there must have been overflow in every direction. This may perhaps account for the gravel deposits along the course of Mill creek, especially near its mouth, for the deposits of sand and gravel in out of the way places, as at Sibley, Sheldon and in the region about Larrabee and north. We have also in our present hypothesis at least a partial clearing up of some of the peculiar drainage features that have been a mystery as we have heretofore attempted to account for the present topography of O'Brien and Clay counties. We may reflect that the erosion operations that had been begun toward the east were by the advent and residence of the Wisconsin ice all for a long time almost entirely suspended; in some cases, at least, never resumed; hence the marshes and lakes or undrained flats such as have characterized southern Osceola county and northern O'Brien. Southwestern Clay county shows something of the same topography.

In view of our present light we may now also better understand the wonderful erosion features of Waterman creek already discussed in the report of O'Brien county. Attention is there called to the remarkable newness of the erosion processes especially as noted in Grant and Waterman townships. It was also suggested that the Little Sioux is a tributary of Waterman creek rather than the reverse. This idea is strongly confirmed. Until the Wisconsin ice pushed across Buena Vista county, Waterman creek was a simple prairie stream, not unlike the upper part of the Floyd, though probably not quite so deeply eroded, flowing southward in the present channel—all uneroded, of course,—of the Sioux river south through Cherokee. Presently, however, Brooke's creek, from the neighborhood of Linn Grove on, began to play the part of drainage outlet for a melting glacier. How rapidly the little creek and the channel of the lower part of the Waterman now became eroded, we may easily imagine. A great ditch was cut in the soft old drift from the present mouth of Brooke's creek to the bluffs of the Missouri, and the upper part

of the Waterman was left to cut back its channel by the use of storm water probably at first by a succession of falls, certainly by an erosion of most precipitous character. The erosion of Waterman creek is accordingly the most recent in the whole country; in fact, it is even now in progress. It has no great gravel trains for the reason that it never drained the ice, at least, not to any considerable extent; its walls are falling in with each recurring spring, almost with every heavy rain, and it is gradually cutting back into the general terrene, much as a ditch sometimes cuts back in a prairie field when the sod is broken.

The remains of once used river channels are not the least interesting and instructive features of the landscape, confirmatory in the highest degree of our present argument. The abandoned channel of the Boyer at Wall Lake has been already mentioned. There are other bits of this old channel, all unfilled, still further north, in Jackson, Delaware and Eden townships of Sac county, and to some extent in Providence township of Buena Vista county. Then we have the great pit in Logan township of Clay county, referred to in an earlier report as a valley of construction; possibly so in part but more likely as we now see a fragment of an old-time river channel. It is probable that other curious misplaced valleys in other northwestern counties adjacent to the border of the drift may have had a similar history, but time has not allowed more exact investigation.

For the industrious Buena Vista county farmer who may perchance read these lines in his quiet home, it will seem a thing hard to believe much less to realize, that in times, even as history reads, not so long gone by, all the landscape about Peterson and Linn Grove and their hills was girt by a wall of ice, to the north, to the east, to the south, a wall probably scores of feet in height, gray and somber, from whose crumbling foot and base streamed persistent fountains flooding the whole country with their turbid waters and even choking up the affluent streams with unheard of loads of sand and gravel. And yet such seems to be the undoubted history of all this prairie region. On no other theory divinable so far, may its peculiarities be understood, much less explained. Of course, such a theory asks credence on other grounds than the mere fact that it fits the situation. Evidence

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clouds to descend as showers all up and down the eastern counties. But with the progress of our agriculture these surface waters have almost entirely disappeared, hurried away by our finer systems of drainage to the rivers and to the sea, and the immediate source of local showers for Iowa has disappeared as well. We are probably too near this situation yet, rightly to understand it or to reckon accurately the change we have effected; but the case will certainly bear investigation and all the most exact observation of those in position to observe will be needed to enable us wisely to use the resources of this great state and to prevent our civilization from self-injury, if not self destruction.

The Wisconsin lands are in some places not a little incumbered with bowlders; but these have proved of great value everywhere as building stone where no other rock was at all accessible. West of the moraine and its immediate vicinage there are bowlders only where these have been exposed and accumulated by the later processes of erosion, as along the banks, ravines, of the Little Sioux and of Mill creek. The scarcity of such rock south and west of the latter stream is remarkable and even notorious. The famous Pilot Rock south of Cherokee is a remarkable example of a bowlder of the older drift, long buried but now, probably since Wisconsin times, uncovered by erosion. This rock has been quarried again and again, and is likely to be finally utterly destroyed and carried away. It is in more senses than one a historic landmark and surely deserves a better fate. The bowlders that strew the hillsides above the city of Cherokee are probably all set free by similar erosional agencies, although some of them may be of Wisconsin time, brought down, as already suggested, in floating ice. The bowlders about Sioux Rapids are apparently of Wisconsin age; one massive limestone block near the upper railway station can hardly belong to the older drift.

But in general the soils of the counties here discussed, whatever their nature, whatever their foundations, are of the finest quality, and yield to husbandry, year after year, with undiminished vigor, the varied crops which belong to this latitude in the great Mississippi valley.

Brick and Tile.

Brick and tile are both extensively manufactured in both counties, more attention being paid to tile, for which in Buena Vista county there has been a great demand. At Sioux Rapids Mr. J. F. Cooley manufactured in the year 1900 some 500,000 bricks and 600,000 tiles. The brick is rather soft, but answers every purpose for inside work. The tiles are said to be of the first grade. The material is derived from a fine alluvial deposit close by the river, apparently a bed of silt, which possibly reaches the Kansan blue clay. At Linn Grove, a little farther down the river. a similar deposit affords material for the manufacture of considerable quantities of both brick and tile. At both points coal is the fuel employed and it must be brought from a distance, even coming, some of it, as reported, from southern Iowa. At Storm Lake a similar bed of what seemed to be silt is worked profitably in the manufacture of soft brick and tiling of various sizes but fair quality, all rapidly taken up by the local demand.

At Cherokee Mr. J. W. Townsend manufactures some two and one-half million brick per year and 100,000 tiles. Coal is, of course, the fuel employed; said to come from the Webster county mines. The clay, rather sandy, is brought from an adjacent hill to the kilns on the west bank of the river. The exposure has been brought about by recent erosion but belongs to pre-Wisconsin drift. It forms a part of the general body of the local drift and is capped by loess though of impure character. Beneath is a distinct stratum of sand which in turn rests upon what is probably the omnipresent blue clay. The lower layers were not well exposed at the time of our visit, but the section as it then appeared was approximately as follows:

	FEET.
4. Dark orange colored loess	6
3. Fine, silt-like, sandy clay, not unlike the loess of the Missouri hills	20
2. Sand	1
1. Blue clay	3

No. 3 where exposed on the face of the bluff by natural erosion shows abundant loess-kindchen.

The brick manufactured by Mr. Townsend are when well

burned hard, of a dark yellowish brown color, and suitable for all sorts of construction. It is a curious fact worth noting, perhaps, that many years ago an attempt was made near Marcus to burn brick, using the wild hay of the prairies as fuel. The experiment seems to have been only partially successful. But there ought to be found good brick clay at Marcus, particularly to the south of that village. Just at the town the loess deposits are somewhat scanty, but the material is abundant in various places in the township south, and is also not lacking three or four miles north of the corporation.

Gravels.

In both the counties here discussed there are unlimited supplies of gravel suitable for the preparation of highways. When once the era of good roads actually arrives these gravel deposits will assume more nearly their real value, that is, they will be better appreciated than now. Nevertheless, in the towns of Cherokee county, and in both city and country in Buena Vista county, gravel is today the road material. An organized effort for the use of this material, extending the paved or graveled road year by year, would soon make the country roads of all northwestern Iowa the very best in the state.

Water Supply.

Cherokee county is favored by the presence of two fine perennial streams, the Little Sioux river and Mill creek. These extend across the county in such a way as to be very convenient to hundreds of farmers and stock-raisers. The volume of water in the river is sufficient for water-power, and at Cherokee it was formerly used for milling purposes. At the present writing there is no water power in either county except the small dam at Sioux Rapids. This has recently been renewed and power sufficient for a grist-mill seems to have been easily obtained. In each county there is rather an unusual number of springs, and these are of greatest service in the localities where they occur. At the county farm in Buena Vista county spring water is conveyed to the buildings and farm houses by means of an hydraulic ram. However, in both counties the principal reliance for water is upon

wells. These vary very greatly in depth. It would seem that deep wells until very recently have not been found necessary. Reference has already been made to the effort at deep drilling made by the railway people near Marcus, and we occasionally hear of a well 300 to 500 feet deep, "to get through the blue clay": but most of the wells in Cherokee county are very shallow, not more than fifteen feet, some of them, and scarcely any more than thirty feet. South of Quimby a short distance are two flowing wells said to be about 120 feet in depth and through the blue clay, but the information in regard to the wells was meager, as indeed with reference to nearly all the deep wells said to occur in this county. As a rule no record at all is kept of anything except depth, and once the land changes hands, or the man who paid for sinking the well disappears, it is impossible to get any accurate information. The value of the careful well-digger's data is great and they might with advantage in each county be made a matter of public record.

In Buena Vista county deep wells are also the exception and were heard of only southwest of the lake and west of Brooke's creek. However, on section 17 in Grant township there is a well 140 feet deep, in which is reported 20 feet to the blue clay, 70 feet of blue clay and then yellow clay and gravel to quicksand and water. At Newell is a well where the blue clay was reached at the depth of only 12 feet, but beyond that depth the record is not very satisfactory, although the well is reported 240 feet deep.

In general it may be said that the two counties are not only well watered in the ordinary sense of that term, but the supply from wells is if anything more than ordinarily accessible.

ACKNOWLEDGMENTS.

In the prosecution of the work of which these pages offer a brief report the author has enjoyed the constant encouragement and assistance of the general officers of the Survey. He would also here record his sense of obligation to Mr. W. J. Harnahan, chief engineer of the Illinois Central railway, for data in reference to the thickness of the drift in Cherokee county. The citizens of the two counties herein described have shown constant

interest in the prosecution of the work and many of them without specifying by name are entitled to the thanks of the Survey. The map of Cherokee county is based upon one loaned the Survey by Messrs. Moore and Chick of Cherokee, and to Mr. A. O. Whedon of the same city we are indebted for the negative from which has been prepared the illustration showing Pilot Rock. Thanks are also due Mr. C. E. Jacobs of Sioux Rapids for many favors.

FORESTRY NOTES.

By the testimony of all pioneers the original forest growth of Buena Vista was limited to that part of the valley of the Little Sioux that falls within the northern limits of the county. It is reported that in the neighborhood of Storm lake there was not a single tree, unless we might perhaps so dignify a few willow bushes discoverable near the western end. When we recall the somewhat abundant development of forest trees of large size, primeval at Okoboji we are probably at first surprised that no such vegetation found similar development here. The explanation of the situation is to be sought in the different topographic surroundings of the two lakes. The principal forest of Okoboji was almost entirely surrounded by water, and so protected from the fires of the northwest and west as they came in their perennial destruction. There is nothing at Storm lake either in the distribution of water or in the configuration of the land to offer any slightest protection to a growth of trees. There is but one lake, and the shore line is uniform, almost without any indentations or bays except to the west where it is flanked by marshes and here alone certain tree-like vegetation is reported to have been found.

But in the valley of the Little Sioux the case is different. Here an unusual number of forest species has maintained itself through past centuries, and these species are still represented by beautiful groves of thrifty, shapely young trees, the so-called second growth. The trees primeval, as seen by the pioneer, were, however, much scattered. They were generally old trees and although as remarked, representing many species, they yet formed nowhere a real forest. Today genuine forest conditions obtain in

many places. There is a beautiful native grove near Sioux Rapids; another, somewhat smaller at Linn Grove; while around the homestead of Mr. Brooke in section 14, Brooke township, is one if the finest native groves in northwest Iowa. The old trees which attracted first the attention and interest of Mr. Brooke are still standing (Fig. 59) surrounded now by hun-

FIG. 59. Where the prairie meets the forest. View taken looking west of north, on the farm of Wm. Brooke, Brooke township, Buena Vista county, Iowa.

dreds of their descendants which form the densest kind of a forest down the hillside. On the summit of the ridge above the residence the boundary between the two floras, woodland and prairie, is beautifully shown.

It is a curious fact that in all these native groves the bur oak always occupies the outmost post, forms the vanguard, the very foremost line. Where no other persisted or withstood the onset of fire and storm there stands the bur oak, gnarled and twisted, shorn and shortened, it is true, but still holding its ground until now that it has passed under the control of civilized man the species finds unexpected relief and young bur oaks are the characteristic feature of every uncultivated hillside along the Sioux.

But if forests are not part of the natural wealth of Buena Vista county, this is no reason why trees may not form a conspicuous feature of the landscape now. Some of the finest, most woodland-looking groves in the country are to be seen today around that

very Storm lake, once so bare and wind-swept. Planted groves adorn the whole country. In the city of Storm Lake may be seen most of the ornamental varieties of shrubs and trees that have place in the most favored grounds in other sections of the northern United States.

In Cherokee county very similar conditions marked the original valley and plain; that is the woodland species of plants were sparsely represented; in the deep gulches, on the steep hillsides by the Little Sioux and in protected corners there was here and there a tree or a clump of arboreous vegetation, but the wide area of the county was entirely treeless. Today the country might almost be described as well wooded. The original forest area has spread amazingly, and if not destroyed by the act of man would speedily cover all the steeper and less valuable slopes along creek and river. There is a fine body of second growth on the east side of the river near Cherokee, and patches of native trees occur all the way down, here and there, to Washta. Some of the primeval forest still stands in the neighborhood of Quimby. Some planted groves on the farms are also very beautiful and have established real forest conditions. The great trouble in the whole situation is that forestry and pasturage cannot go on together. If a farmer wishes to see his grove thrive and do him highest service he will not subject it to the injurious trampling of herds of cattle. Many fine groves in northern Iowa are now being ruined in this way. With the rapid occupancy of the more fertile portions of our country and the rapid destruction of our native supplies of lumber and forest products, the time is rapidly nearing, if not already at hand, when the timber lot will be as valuable an adjunct to the well-appointed farm as the pasture lot. But the same land cannot be used for both purposes. As well attempt to raise corn in the meadow. If the farmer desires a grove to shade and shelter him and his cattle, to furnish him a perennial supply of fuel and of wood to be used for all sorts of purposes about the farm to say nothing of the adornment of his holding, he can have it in northwestern Iowa as well as elsewhere in the state, but he must take care of it, at least to the extent of giving the trees a chance. Furthermore the scant native growth of the counties we have been studying is yet all-

sufficient to demonstrate that our farmer is by no means limited to the familiar willow and box-elder or white maple; he may plant all sorts of trees, ash, walnut, oak, basswood, besides those forms ordinarily used for ornament, such as pines and larches.

Since fire has been eliminated from the problem, the great enemies of the trees, enemies not under human control, are drought and the wind. The counties here considered have shown a remarkable endurance under the most trying conditions of drought, and it is a fact that the trees themselves, by their increasing numbers, protect each other from the winds, if they do not ameliorate these atmospheric conditions as a whole. There are those who have lived long in Iowa who think and believe that the occupancy of these prairies and the planting of them with trees in thousands upon thousands has greatly changed our climate. However this may be, there is no doubt whatever of the protection afforded locally to a homestead by a well situated, well cared for grove of trees. It is doubtful if the northwest prairie were habitable, at least by enlightened people, without the aid and assistance brought by plantations of trees.

The native woody plants of Cherokee and Buena Vista counties, so far as noted, are as follows:

Tilia americana Linn. Basswood or Linden.

A most valuable and hardy tree; a rapid grower, beautiful and clean. A fine shade tree nor less desirable in the grove where its habit of stooling, or branching from the base makes it valuable as a windbreak. The flowers are beautiful and odorous and famous for bees, yielding a preferred variety of limpid honey. This tree is native to the banks of the Little Sioux and even of Mill creek. Large trees are reported to have been sawed into lumber by the pioneer. The lumber is soft, strong, but straight-grained and very easy to work.

Xanthoxylon americanum Mill. Prickly Ash.

A very hardy, quick-growing ornamental shrub, easily transplanted, with spicy leaves and twigs, small early flowers followed in August by bright, red, berry-like fruit which presently breaks open, revealing in each fruit a pair of shining black seeds. Very common along the valley of the river in undisturbed bottom lands. Valuable only for ornament.

Acer saccharinum Linn. *Acer dasycarpum* Ehrhart and of the books generally. Common soft Maple or White Maple.

Everywhere planted for shelter and for groves and now probably indigenous in both counties along the river bottoms above the dam at Sioux Rapids, etc. A most valuable tree and one of the best servants and friends of the farmer and the pioneer, deserves a place in the Hall of Fame of all the valley states. It grows rapidly, endures abuse of every sort, shades and shelters the homes of men and offers convenient covert to the herds and flocks. Nor less has this tree especially been of service to our friends, the population of the air. Robins and thrushes frequent the maple groves and build their nests in regions that only recently knew them not. Nay more, the present writer saw a company of bluebirds, in this year of grace 1902, sunning themselves on the leafless branches of the maples of a farm in northern O'Brien county. People farther south and east think themselves privileged to see and hear these beautiful American birds, and the farmers of the northwest have reason to congratulate themselves that their tree planting offers an inviting summer residence to our choicest and most industrious and beneficent birds of song.

Acer negundo Linn. Box Elder.

This exceedingly useful and common tree is happily native to all the northwest. Planted as a windbreak and for shade this tree has done its part in making the country. It is not desirable as a street tree, but as a starter, as a nurse in the planting of other species, it is invaluable.

Rhus glabra Linn. Sumac.

This is the common sumac of all our northern woods. It is useful as an ornamental plant only. Its curious flowers, its bunches of deep red fruit, and above all, its glowing autumnal foliage, make it well worthy of preservation and of consideration in the planting of grove and lawn. It spreads rapidly from the roots and from a single shoot will soon cover a hillside if left to itself. The plant is not poisonous, as many people suppose. The poison sumac is quite a different thing. It is likely to be found everywhere, although no native specimens were observed; but it has been scattered by birds and other animals far and wide and

is probably found today in every county. It is native about the lakes in the north. It may easily be distinguished by the three foliolate, three-parted leaves and the loose clusters of whitish berry-like fruit that hangs all winter upon the leafless stem. In our part of the country poison sumac is ordinarily in form a small inconspicuous shrub; sometimes, however, it assumes the climbing habit and ascends trees, fence posts, etc. In this form it must be carefully distinguished from the Virginia creeper, an elegant native climber, not poisonous, with five leaflets and producing in autumn dark blue fruit like that of the wild grape.

Prunus americana Marsh. Wild Plum.

A common tree forming thickets here and there by the streams. An exceptionally fine ornamental tree; nothing has handsomer or sweeter bloom. Inured to the severest climatic conditions of every sort, it is nevertheless rather easily destroyed by cattle. Makes a fine border to the grove, a thicket covert for birds and is in every way worthy of preservation, aside from the tang of its wild sharp fruit.

Prunus virginiana Linn. Choke Cherry.

A not infrequent little tree in the native groves up and down the Sioux. Useful only as an ornamental tree, since it gives out in spring rather showy clusters of white flowers, succeeded later on by abundance of shiny black fruit, the delight of birds.

Prunus serotina Ehr. Wild Cherry.

This occurs sparingly along the river in several places. It appears also not infrequently in groves, those long ago planted offering opportunity for this and all sorts of species whose seeds may be carried by birds. A valuable tree for lumber and of rather rapid growth.

Pyrus iowensis Wood. Crab Apple. Iowa Crab Apple.

Common along streams and growing in thickets even by the roadside everywhere. One of the most beautiful ornamental plants we have. Its disposition to spring up from the root prejudices the farmer sometimes against it, but after all it is easily controlled and with its prolific bloom in the early year it certainly makes amends for all the trouble it costs.

Crategus coccinea Linn. Hawthorne, Red Haw.

This species was noted near Cherokee and doubtless occurs all

along the river and is to be commended in much the same way as the last.

Symphoricarpus occidentalis Link. Wolf Berry.

This is a clean little shrub growing in the shady woods and by the borders of thickets everywhere near the stream. It has very handsome and showy clusters of flowers that come in July and continue blooming for some weeks. In the fall come the snow berries, an attractive fruit hanging on the shrub often long after the leaves have fallen.

Sambucus canadensis Linn.

Not common. Escaped from cultivation here and there. Found in some places in gardens where the fruit is appreciated.

Viburnum lentago Linn. Black Haw.

Rare along the river. Reported from several points but not observed. A handsome little tree, useful for decorative purposes and in great popular esteem for its peculiar fruit.

Fraxinus americana Linn. White Ash.

Native to both countries and everywhere commonly planted. One of our finest forest trees; clean, hardy, making a pleasant grove and furnishing excellent timber for all sorts of uses as well as the best of fuel. It should be more extensively planted; doubtless would be were it not that it grows more slowly than some other species and wearies thus the patience of the average planter. But there is no reason why such trees should not now supplant the cheaper and less desirable varieties.

Ulmus americana Linn. American Elm. Common White Elm.

This is another common and hardy species. There is one typical specimen of this tree just north of Sioux Rapids that is as fine as any elm in Iowa. Most specimens noted were low and spreading; that just cited is tall and graceful and in every way one of the finest of its class. The elm is our street tree; no other comes near it for such purpose. With the progress of the years the long limbs sometimes meet above the street and offer to the fortunate passer-by a perfect Gothic arch of leafy symmetry.

Ulmus fulva Michaux. Slippery Elm.

Reported as occurring along the river in both counties. Said to have been at one time abundant near Quimby. A fine tree but not nearly so valuable as its kindred species. The bark is

reputed to possess medicinal properties and doubtless has its uses in domestic medicine. Its wood when dried in winter is said to be among the best for fencing, but we must have respect to the time of cutting and curing.

Juglans nigra Linn. Black Walnut.

This most valuable of all native trees is fortunately also native of the counties of northwestern Iowa. Specimens may be seen in the ravines north of Sioux Rapids and large trees are reported as once not rare along the bluffs throughout Cherokee county. Trees are easily reared from the seed and they grow at first with surprising rapidity in our prairie soils. They are not good, however, when placed alone; they must be in groves and planted with other trees at least for some years. These nurse trees may later on be cut out when forest conditions have been once established. It is a wonder that more attention is not given in northern Iowa to the cultivation of this tree. It is doubtless a slow crop, but is certainly sure and immensely remunerative. In twenty-five years a crop of walnut trees will pay an enormous interest. The grove of Senator Whiting at Monona and that of Mr. James Brown in Battle township of Ida county are famous.

Carya amara Nuttall. Pig Nut. Bitter Nut.

This is the only hickory noticed in the northwest. It occurs on the wood-covered slopes along the river not uncommonly. The tree is worthy a place in our list of trees to be cared for; its wood, though not so valuable as that of the shell bark hickory, is yet of good quality and is one of the few hard woods here available. Useful for tool handles and for all purposes where strength and solidity is demanded.

Corylus americana Walt. Hazel. American Hazel.

Common wherever there is native woodland. The hazel is a natural nurse for other species. It occupies the border of the existing woods, holds the snow amid its slender twigs and so gives the seedlings of the oak and other forms protection at times critical. A pleasant little bush much appreciated by boys of sound mind and body and worthy of preservation for this reason if for no other.

Ostrya virginiana Willdenow. Ironwood.

A valuable little tree of slow growth and exceedingly hard texture, as the popular name implies. Not uncommon along the river and on the steep banks of Wild creek. The wood is of use in the same way as is that of the hickory.

Populus deltoidea Marshall. Cottonwood.

This is the universal tree of all the prairie country, east or west. This tree is certainly chief accessory before and in the fact, to all that has been done or attempted under the United States "timber claim" laws. Scarcely ever was any other species selected to meet the conditions of that law. Under the timber laws of our own state the tree also bore an important part, and many a fragmentary plantation is still in evidence to certify to the stimulating effect of all this economic legislation. The fact is the cottonwood is fine for certain uses. It grows with great rapidity, is hardy, enduring winter's cold and summer's drought and heat, but it does not make good plantations. It may be used around the outside, especially to the east or west, but does not do well in the center. There are beautiful rows of cottonwoods in all parts of both counties here described.

Quercus macrocarpa Michaux. Bur Oak.

This is *the* oak of all northwestern Iowa. It occurs in all forms and of all shapes and sizes. It is the common "scrub" of the gulches and ravines where trees a yard in height may be found in full fruit, nor less is it the famous tree of the pioneer to which he was indebted for lumber and for wood. Mr. Brooke has some fine specimens of the old trees near his home in Brooke township, Buena Vista county. Our illustration (Fig. 59) shows some of these.

Quercus rubra Linn. Red Oak.

This is the only oak beside the bur oak so far noticed in this portion of the state. It is not infrequent along the banks of the river at Sioux Rapids, Linn Grove, Cherokee, etc. The specimens noted are all of small size and useful for fuel only. This species comes up well from the stump if the trees be cut in winter, and is valuable where it is desirable to keep a perpetual grove of growing forest which shall yield constant supplies of second growth wood.

Juniperus virginiana Linn. Red Cedar. Cedar. Juniper.

This is the only native conifer of northwestern Iowa. It is said to have been once common near Cherokee, along the bluffy banks of the river, but it has certainly largely, if not entirely, disappeared. In time the tree reaches, even in this prairie country, considerable size, but its chief value lies in its desirability as an ornamental tree for the lawn or dooryard. It endures shade much better than evergreens generally and is a favorite on the farms. Makes fairly good windbreaks and can be used along the north side of the grove or plantation where the lack of light and sun in no wise incommodes it.

Besides the species here enumerated by name, there are several species of willow, some certainly native, which have not been with certainty identified. Mention has not been made either of many introduced trees planted in many parts of these counties, mulberries, poplars, fruit-trees of all sorts, which appear to thrive here as well as in some other portions of Iowa. The usual conifers also are here planted with good effect, and there seems no reason why the people of these counties may not have the advantage of the use of all or nearly all the arboreous species that are found commonly capable of enduring the somewhat trying and inhospitable climate of this state.

BY

T.H.MACBRIDE
1902.

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GEOLOGY OF JEFFERSON COUNTY

BY

J. A. UDDEN.

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CONTENTS.

INTRODUCTION.

AREA AND LOCATION.

Jefferson county comprises an area of 432 square miles. It lies in the southeastern part of the state, extending to within thirty-six miles of the Mississippi river and to within twenty miles of the Missouri line. It includes all of ranges eight, nine, ten and eleven west of the fifth principal meridian and all of townships seventy-one, seventy-two and seventy-three north. On the east it is bounded by Henry county, on the south by Van

Buren, on the west by Wapello, and on the north by Keokuk and Washington counties, being included in a rectangle measuring twenty-four miles from east to west and eighteen miles from north to south.

EARLIER INVESTIGATIONS.

The geologists who have previously made a study of the formations exposed in this county are A. H. Worthen, who made a rapid survey of the region in the summer of 1857*, and Prof. C. A. White, who was State Geologist ten years later.† Not being traversed by any of the larger streams, to which the attention of these early surveys was necessarily mainly directed, the field was not as closely studied here as in some other counties, and the published reports were very brief, giving only the main features. More data, bearing especially on the production of coal, were lately obtained and published by C. R. Keyes in the volumes of the present survey.‡ Recently Mr. Frank Leverett has described and explained the significance of a high terrace which occurs along the Skunk river in the northeast part of the county.§

PHYSIOGRAPHY.

TOPOGRAPHY.

The ruling feature in the topography of the county is the surface of an old drift plain, which has an average elevation for the whole area of about 770 feet above sea level. It has a general slope to the south of about two feet per mile, and to the east of nearly three feet per mile, while from the northwest to the southeast its general descent is about five feet to the mile. This drift plain is the result of the deposition of the bowlder clay by extensive inland ice fields. It is far from being in its original condition. The long continued action of erosion subsequent to the disappearance of the ice has greatly changed its original aspect. Rivers, creeks and smaller tributary streams have sunk their valleys and gullies into it until their beds now lie from 50 to 150

* Worthen: Geology of Iowa: James Hall, Vol. I, pp. 231-239, 1858.
† White: Second Annual Report State Geologist, pp. 94-96, 1868; also Geology of Iowa, Vol. II, p 273, 1870.
‡ Keyes: Iowa Geol. Surv., Vol. I, p. 120; also Vol. II, pp. 393-402.
§ Leverett; Monograph XXXVIII, U. S. Geol. Surv., p. 92.

feet below its surface. Much of its surface, especially such parts as have not suffered erosion, has later been buried by a covering of loess, varying in depth from eight to sixteen feet. In this modified condition the land now presents various topographic features, which may be classified as: (1) flat uplands; (2) upland slopes; (3) terraces; and, (4) bottom lands.

The Flat Uplands.—The flat uplands are such parts of the original drift plain as have not yet been perceptibly affected by erosion through the backing up of the drainage lines and drainage slopes. They lie between these, forming the divides, and their borders run into the slopes. Except in a few places near some of the headwaters of the longest tributaries to the larger streams, this border is quite well marked by a gradual but well marked change in slope from usually less than fifty feet in a mile on the upland plain to several or many times this amount in the slopes leading down into the smallest drainage branches. Midway between two adjacent drainage basins the upland flats are nearly or quite level except for the general tilting of the whole plain, but as we approach the drainage lines on either side there is usually a slight, almost imperceptible slope. In the direction of the larger streams this slope seldom amounts to more than ten feet per mile, but on the sides of those strips of upland which extend from the main divides to form the divides separating the smaller ravines, it is frequently more.

The surface of these uplands is otherwise notably flat and even. It is highest above the headwaters of the longest streams, and its lowest stretches often appear in places where streams join. But all of these differences in elevation are invariably very gentle and gradual. Only a single instance of a mound-like elevation on the uplands was noted in the course of the survey. This is a little north of the center of section 7 in Liberty township, about three-quarters of a mile northwest of Libertyville. At this place the surface has a rather well marked bulge of ten or fifteen feet above the general level. This elevated tract covers an area of some forty acres. Shallow depressions are somewhat more common along the highest lines of the widest divides and these may have an area of from a fraction of an acre to several acres.

Estimates made on the several townships give an average of from one-fourth to one-fifth of the total area of the county to the flat uplands. They are most extensive in Polk, Black Hawk and Des Moines townships and have been most extensively invaded by the creeks in Walnut, Lockridge and Locust Grove. In Polk township there are entire tracts which are a mile wide, but otherwise the habit of the flats is to form strips from twenty rods to half a mile in width between the streams. Four-fifths of their whole extent in this county is believed to consist of such strips. In not a few instances these reach far out from the main divides and terminate in the very bluffs of the main streams. In Jefferson county this is perhaps most common on the south side of Cedar river.

The Upland Slopes.—The upland slopes extend from the sinuous margins of the flats down to the bottoms of the streams. They occupy the greater part of the surface of the county. The greatest pitch of these slopes prevails in places where the larger streams have encroached upon the uplands by widening the bottom lands. Recent instances of sapping are however quite scarce, especially in places where the streams do not cut below the base of the drift. The meanders of some of the larger streams may be followed for several miles without coming to a place where the bluffs are now being attacked so as to expose fresh drift. The width of the slopes is most commonly from one-eighth to one-half mile and the descent is from 50 to 150 feet. The latter height is attained in some places in Walnut township along the tributaries to Skunk river and in the southwest part of Des Moines township approaching the Des Moines river. The slopes of least relief occur along the headwaters of the longest tributaries to the larger streams. The greatest pitch is nearly always somewhat below the middle of the slope. Below this the slope continues downward in a curve having a concave profile, and above, it runs in a curve which has a somewhat extended convex profile. Following the slopes in the direction of their linear extension, on the sides of the water ways, we find that they form an endless succession of loops and curves determined by the course of the larger streams, creeks and the ultimate branches of all their affluents. It is evident that the slopes

to less than seventy-five feet below the same uplands in case of the narrow alluvial tracts following the smaller divisions of their tributaries. The bottom lands of Skunk river average a little more than a mile in width, being broadest just above the mouth of Walnut creek where they reach a mile and a half from bluff to bluff. They have an elevation of about 585 feet above sea level, sloping south about two feet per mile. The flood plain of Cedar creek varies greatly in width. In Round Prairie and in the east half of Cedar township it is narrow and at times entirely absent. The stream winds along in a rocky canyon with walls from forty to seventy feet high and from a few rods to perhaps one-fourth of a mile apart. Above the mouth of Crow creek it widens out and for the next five miles maintains a width of from half a mile to a mile. Then for about three miles within the boundaries of Fairfield township it narrows to half a mile. Above this it again widens to about three-fourths of a mile and more ,in the east half of Locust Grove township. For the remaining four miles of its course in this county it is mostly less than a quarter of a mile wide. Examining the material on which the work of erosion has been performed by this stream we find that the width of its bottoms corresponds inversely to the hardness of the materials on which it has had to work. In the region of the limestone the bottoms are narrow or none. In the region where the Coal Measure shales and limestones have been worked upon the width is from one-fourth to one-half mile, and where there is only drift the bottoms widen out to as much as a mile. The elevation of the Cedar creek flood plain is about 685 feet above sea level at the west boundary of the county and about 620 feet below the mouth of Rock creek on the south boundary. The bottoms of the smaller streams, such as Walnut creek and its branches, Turkey, Brush, Wolf, Rock and Crow creeks, the two Competine creeks, Black creek and Lick creek average at least an eighth of a mile in width and sometimes expand to twice this measure, vanishing only within a mile or so of the ultimate sources of the streams. The habit of contracting in places where the channel goes below the surface of the bed rock is in their case even more conspicuous. It is universal and the writer has not observed a single exception to the rule that the bottoms are narrow in places

where outcrops of bed rock occur, and wide where the bluffs are composed of drift all the way down. The extent of the contraction of the valleys is usually proportionate to the rise of the rock. The higher this lies the more narrow the valley, and where the valleys dilate farthest it is useless to look for good exposures of the country rock.

DRAINAGE.

The drainage bears everywhere the mark of maturity and has suffered no recent changes. The larger streams probably follow drainage lines existing before the drift was laid down. The courses of the minor stream have evidently been established subsequent to the time of the ice invasions. About fifty square miles of the area of the county drain into the Des Moines system. The remaining 382 square miles belong to the Skunk river system and is divided among its several tributaries as follows:

	SQUARE MILES.
Cedar creek basin	190
Walnut creek basin	82
Brush creek basin	20
Other basins	70

The Cedar creek basin averages some twelve miles in width and extends through the south part of the county from west-northwest to east-southeast, reaching nearly to the northwest corner. Its north tributaries reach out from five to eight miles, while those on the south side drain a strip only about three or four miles wide. Most of the smaller drainage basins are likewise elongated in form and their longer axes have the same general trend. The exceptions to this rule consist of some basins which drain more nearly either north or south. These are less elongated in outline and as a consequence the branches of their creeks spread more. Such are the tributaries to the Des Moines river in the southwest part of the county and all the smaller tributaries to Cedar creek.

The land is at present almost everywhere well drained. The only exceptions consist of some few tracts of low bottom land and some shallow depressions on the widest upland flats, already referred to. Before the land was brought under cultivation these

shallow depressions on the uplands were partly filled with water after rains and this sometimes stood for an entire season. These pools were sought by the hunters, in the pioneer days, for geese and ducks. Some were conspicuous enough to receive local names. "Devil's Lake" covered at times a few acres a little east of the center of the southwest quarter of section 20 in Polk township. Other ponds occurred in the southwest quarter of section 12 and in section 13 in the same township, in the northeast quarter of section 32 in Black Hawk township, and in the southwest quarter of section 12 and the northeast quarter of section 2 in Fairfield township. At that time the uplands were less well drained than at present, and where we now find the best farms the land was at first regarded as being too wet for agricultural purposes. Most or all of the rainfall was then, as it is now, absorbed by the ground or evaporated, the surface slope being too small to drain it off, before it has time to be taken up by the porous loess soil. It escapes from there only by slow seepage and by evaporation.

TABLE OF ELEVATIONS.

STATION.	ALTITUDE.
Batavia. C., B. & Q. (new grade), b	725
Beckwith, C., B. & Q.. a	777
Cedar bridge, C., B. & Q R R., c	702
Cedar bridge, C., R. I. & P. R. R, c	675
County Line, C., R I. & P. R. R, c	788
Fairfield, C., B. & Q. R. R. (new grade), b	775
Glendale, C., B. & Q R. R., a	758
Highest point C., R I & P. R R, c	805
Krum, C. B. & Q R. R. (abandoned road), a	692
Libertyville, C., R. I & P. R R., a	768
Lockridge, C., B. & Q R. R, a	782
Mitchell creek bridge. C., B. & Q R. R. (new road), b	715
Packwood B. & W R. R., c	82[illegible]
Pekin, B. & W. R. R, c	835
Perlee, C., R. I. & P. R. R. (old grade), a	679
Pleasant Plain, C., R I. & P. R. R. (old road), a	749
Shirtz creek bridge, C., B & Q R. R (new road). b	720
Skunk river, near Coppock, c	570
Upland west of Batavia, c	790
Veo, B. & W. R. R., c	790
Woolson, B & W. R R, c	784

Authority: (a) Gannett's Dictionary of Altitudes in U. S.; (b) Engineer's office, C., B. & Q. R. R.; (c) Aneroid measurements by the author.

STRATIGRAPHY.

General Relations of Strata.

In the west half of the north tier of townships the streams have not cut through the drift and no rock exposures have been observed. The thickness of the drift appears to be quite uniform, some 125 feet, although one well record gives 180 feet. Immediately under this lie the Coal Measures, averaging perhaps fifty feet in depth. These have been quite extensively removed on the lowlands, however, and in the northeast part of the county they are absent even on the uplands. The Coal Measures in turn rest on the Saint Louis limestones, shales and sandstones, which belong to the Lower Carboniferous and which average about one hundred feet in depth. The following table will further elucidate the general arrangement of these divisions:

GROUP.	SYSTEM.	SERIES.	STAGE.	SUB-STAGE.
Cenozoic.	Pleistocene.	Recent.	Alluvial and terrace.	
		Post-Kansan.	Loess.	
		Glacial.	Kansan	
			Aftonian.	
			Albertan.	
Palæozoic.	Carboniferous.	Upper Carboniferous.	Des Moines.	
		Lower Carboniferous.	Saint Louis.	Pella.
				Verdi.
				Springvale.

Underlying Formations.—Under the rock seen in the lowermost exposures there is some thirty feet of limestone, with some shale and sandstone, as is shown in the deep well at Ottumwa and also known from exposures in the counties of the east. This is mainly the Augusta limestone, also known as the Keokuk and the Burlington. Below this the Kinderhook shales continue for some 150 feet, under which there is nearly 500 feet of limestone with some included shale. Then the Saint Peter sandstone follows, about 100 feet in thickness, and limestone with some shale run on for 900 feet below this, which is the greatest depth reached by explorations in this region.*

Carboniferous System.

THE SAINT LOUIS.

The lowest formation which appears in exposure in Jefferson county is the Saint Louis, belonging to the upper part of the Lower Carboniferous system. It consists of limestone, marls, sandstones and dolomites of quite varied characters and has an exposed thickness of some eighty feet within the boundaries of the county.

The outcrops of the Saint Louis are to be found only in the valleys of the streams, where the overlying Coal Measures, which constitute the bed rock over most of the area, have been removed. In the northeast half of Walnut township and in places farther west along the north boundary of the county the drift no doubt rests directly on the Saint Louis even in the uplands, but the areas of these upland occurences can be made out only approximately owing to the thickness of the drift.

Sections on Burr Oak and other Creeks.—In a ravine which runs east along the south line of section 1 in Walnut township, and in the bluffs to the north, this terrain appears as high up as from 50 to 150 feet above the level of the Skunk river. It occurs also in the northeast quarter of section 2, in the northwest quarter and near the southwest corner of section 11. On Burr Oak creek it is seen at intervals from the east line of section 8 and all the way down to the junction of this creek with the

* Norton; Iowa Geol Surv., Vol. VI, p. 319.

Walnut. In sections 8 and 16 there is limestone, in section 22 the rock consists of arenaceous limestone or sandstone, and still further down, in section 26, there are ledges and seams of dolomitic limestone, marls, and blue shale. These latter beds represent the lowermost division of the Saint Louis beds exposed in the county. A detailed description of two exposures is as follows:

I SECTION IN THE WEST BANK OF BURR OAK CREEK, A LITTLE NORTH OF THE CENTER OF THE SW. ¼ OF THE SW. ¼ OF SEC. 26, WALNUT TOWNSHIP.

		FEET.
9. (2)	Bluish white, laminated, limestone of very fine texture	1
8. (2)	Yellow, marly, dolomitic material	5
7. (2)	Yellow, wavy-bedded mortar-rock with a pure calcareous, and slightly porous matrix, making more than half of the bulk of the rock and being in places without sand. The imbedded rounded sand grains averaging somewhat less than one millimeter in diameter in all samples examined, but range up to five times this size. The largest of the siliceous fragments are angular and consist of chert	4
6. (2)	Yellow, mortar-rock, with a pure calcareous and slightly porous matrix. The sand constitutes about one-half of the bulk of the rock, and consists of rounded grains of quartz averaging less than one millimeter in diameter, and ranging up to two millimeters. There are also fragments of chert from one-half to three centimeters in diameter. These have their surfaces frequently marked by shallow concave hollows, apparently produced by etching, as by solution. Yet the texture of the bed is very variable. In places it is traversed by thin, long and curving fissures which are filled with clear calcite	⅔
5.	A band of yellowish gray chert of rather even thickness	¼
4. (1)	Yellow or blue, marly, magnesian limestone with band of chert. A hand specimen was observed to be without any sand. It had minute porosities, apparently due to the removal of some organic fragments. Some of these were minute, straight, tubules. Imprints of a Productus were noted	3½

Underlying Formations.—Under the rock seen in the lowermost exposures there is some thirty feet of limestone, with some shale and sandstone, as is shown in the deep well at Ottumwa and also known from exposures in the counties of the east. This is mainly the Augusta limestone, also known as the Keokuk and the Burlington. Below this the Kinderhook shales continue for some 150 feet, under which there is nearly 500 feet of limestone with some included shale. Then the Saint Peter sandstone follows, about 100 feet in thickness, and limestone with some shale run on for 900 feet below this, which is the greatest depth reached by explorations in this region.*

Carboniferous System.

THE SAINT LOUIS.

The lowest formation which appears in exposure in Jefferson county is the Saint Louis, belonging to the upper part of the Lower Carboniferous system. It consists of limestone, marls, sandstones and dolomites of quite varied characters and has an exposed thickness of some eighty feet within the boundaries of the county.

The outcrops of the Saint Louis are to be found only in the valleys of the streams, where the overlying Coal Measures, which constitute the bed rock over most of the area, have been removed. In the northeast half of Walnut township and in places farther west along the north boundary of the county the drift no doubt rests directly on the Saint Louis even in the uplands, but the areas of these upland occurences can be made out only approximately owing to the thickness of the drift.

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Walnut. In autumn [illegible]

[illegible]

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		FEET.
9. (2)	Bluish white, laminated, limestone of very fine texture	1
8. (2)	Yellow, marly, dolomitic material	5
7. (2)	Yellow, wavy-bedded mortar-rock with a pure calcareous, and slightly porous matrix, making more than half of the bulk of the rock and being in places without sand. The imbedded rounded sand grains averaging somewhat less than one millimeter in diameter in all samples examined, but range up to five times this size. The largest of the siliceous fragments are angular and consist of chert	4
6. (2)	Yellow, mortar-rock, with a pure calcareous and slightly porous matrix. The sand constitutes about one-half of the bulk of the rock, and consists of rounded grains of quartz averaging less than one millimeter in diameter, and ranging up to two millimeters. There are also fragments of chert from one-half to three centimeters in diameter. These have their surfaces frequently marked by shallow concave hollows, apparently produced by etching, as by solution. Yet the texture of the bed is very variable. In places it is traversed by thin, long and curving fissures which are filled with clear calcite	⅔
5.	A band of yellowish gray chert of rather even thickness	¼
4. (1)	Yellow or blue, marly, magnesian limestone with band of chert. A hand specimen was observed to be without any sand. It had minute porosities, apparently due to the removal of some organic fragments. Some of these were minute, straight, tubules. Imprints of a Productus were noted	3½

		FEET.
3.	(1) Yellow and somewhat indurated magnesian limestone	1/3
2.	(1) Greenish gray, shaly marl with irregular loaf-shaped concretions of tough, gray quartz..	3
1.	(1) Fine-grained, almost compact and partly dolomitic limestone of yellow color and with streaks of imbedded fine sand. On fresh fractures there were seen minute, dark, dendritic blotches as of manganese oxide. The ledge is traversed by thin curving fissures, which are healed mostly with a dark ferruginous cement. Seen in bed of the creek to a depth of about.............	1

II. SECTION IN THE WEST BANK OF BURR OAK CREEK, NEAR THE CENTER OF THE SW. ¼ OF THE SW. ¼ OF SEC. 26, WALNUT TOWNSHIP.

		FEET.
5.	(1) Dull yellow, magnesian limestone	1½
4.	(1) Yellow dolomitic marl	5
3.	(1) Yellow, apparently leached and somewhat dolomitic limestone of fine texture containing fragments of a Productus and Fenestelia	¼
2.	(1) Dull yellow marl, somewhat dolomitic	3
1.	(1) Greenish, slightly calcareous shale containing irregular shaped, loaf-like concretions of a tough gray quartz, somewhat resembling geodes, but differing from these in always having a solid center and in showing no crystals	3

Sections on Walnut Creek.—Following Walnut creek we find the same succession. The lowest rock exposed in the bed of this creek, about one-fourth of a mile west of the center of section 2, Lockridge township, is identical with number 4 in section 1 above, except that it is slightly less dolomitic and that it contains occasional small kernels, or lumps, of compact calcareous material, as if the process of dolomitization were less far advanced. Along the bend to the south which this stream makes in sections 2 and 3 these dolomitic beds are exposed, and above them we find sandy, cross-bedded limestones rising thirty or forty feet. These continue for four miles above and are in turn overlain by brecciated, more calcareous and less sandy limestone ledges, as may be seen in sections 19, 20 and 29 in Walnut township, and in sec-

tions 24, 25 and 26 in Penn township. Still farther up, as in sections 21, 23, 26 and 27, yet higher beds occur above these, in the banks of the main creek and its forks and these consist of quite evenly bedded gray limestones and marls. The cross-bedded sandy rock is particularly well exposed in the right bank of the creek along the east line of the northeast quarter of section 29 in Walnut township. The relation and characteristics of the different divisions are well represented in the following sections:

III. SECTION IN A RAVINE AND IN A STONE QUARRY IN THE SW. ¼ OF THE SE. ¼ OF SEC. 3, LOCKRIDGE TOWNSHIP.

	FEET.
5. (3) White, weathered limestone-breccia, weathering into angular fragments. Some of this breccia is arenaceous, with imbedded pieces of pure white limestone. Occasionally an almost pure sand fills the interstices between the blocks and fragments of the breccia. (Seen above the stone quarry.)	5
4. (3) Yellow clay and marl	3½
3. (2) Porous limestone of dark gray color. It contains occasional nodules of chalcedonic quartz. In some places it gives a faint bituminous odor, when struck by the hammer. It contains a small and variable amount of well rounded sand grains and also of calcareous fragments of a different and finer texture from that of the main matrix. In places the rock contains scattered clear crystals of calcite measuring about one-eighth of an inch in length. These are occasionally dissolved out leaving small cavities. Some of the larger quartz sand grains and small pebbles, which this rock contains, have shallow, concave depressions on the surface. These have apparently been produced by solvent action of the ground water. In three rock specimens, carefully examined, different stages of this etching were noticed. Its extreme result is the production of a porous, calcareous rock with only a few imbedded, angular, siliceous particles. (The main quarry rock in Walgren's quarry)	7
2. (2) Porous, grayish yellow limestone, somewhat irregularly bedded, and considerably af-	

		FEET.
	fected by weathering and leaching (exposed below the quarry)	5
1. (1)	Dolomitic marl, almost stony above and more shaly below. When crushed and examined under the microscope the marly material is seen to consist of very small rhombohedral crystals, which effervesce tardily in moderately strong acids. (Exposed in a ravine below the quarry.)	8

IV. SECTION IN THE LEFT BANK OF WALNUT CREEK, ABOUT TWENTY RODS SOUTHEAST OF THE CENTER OF THE SW. ¼ OF SEC. 20, WALNUT TOWNSHIP.

		FEET.
2. (3 & 4)	Gray, partly brecciated limestone (not well exposed)	20
1. (2)	Sandstone and arenaceous limestone, frequently cross-bedded	25

V. SECTION IN THE SOUTH BANK OF WALNUT CREEK, ABOUT ONE FIFTH OF A MILE WEST OF THE EAST LINE OF SEC. 19, WALNUT TOWNSHIP.

		FEET.
3. (4)	Gray, hard limestone, slightly brecciated and broken, and with some thin seams of marl between some of the ledges	10
2. (3)	A stony marl containing a small and almost spherical Seminula in abundance, and lumps of concretionary limestone, and of oolitic limestone. The oolitic spherules average one half of a millimeter in diameter and are mingled with occasional larger lumps of compact limestone. Most of them are elliptical in cross section and consist of a dark central plate which is surrounded by a light-colored thick envelope, which again is surrounded by a thin crust of dark color on the outside	⅓
1. (3)	Flexed, faulted and brecciated ledges of hard gray limestone	10

VI. SECTION IN THE NORTH BANK OF WALNUT CREEK, AT THE SOUTHEAST CORNER OF SEC. 24, PENN TOWNSHIP.

		FEET.
(2)	Slanting and cross-bedded ledges of limestone alternating with more massive ledges of mortar-rock. The latter is in places seen to have promiscuously arranged, curving, tubular cavities of variable diameter, which are	

	FEET.	
filled with calcite. The mortar-rock consists of a calcareous matrix making from ten per cent to forty per cent of the bulk, and containing imbedded well-rounded sand grains, the prevailing size of which in one hand specimen was from one-third to one-fourth of a millimeter in diameter. In same specimen ninety-eight per cent of the grains consisted of white quartz. The remainder consisted or quartz of an amethyst pink color, bright green grains, and some dark quartz. Some spherical grains of lime carbonate were also observed, and resembled oolotic spherules	12	

VII. SECTION IN THE SOUTH BLUFF OF THE NORTH BRANCH OF WALNUT CREEK NEAR THE SOUTHWEST CORNER OF SEC. 23, PENN TOWNSHIP.

	FEET.	INCHES.
3. (4) Grayish white limestone in thin ledges......	3	
2. (4) Grayish white limestone in a single solid ledge, with curving flattened stems resembling fucoids impressed into the upper surface. It contains, especially near its lower surface, *Pugnax ottumwa* White, *Seminula trinuclea* Hall, and *Spirifer keokuk* Hall.	2½	
1. (4) A thin seam of shaly material containing *Pugnax ottumwa* White, in abundance....		½

VIII. SECTION IN THE NORTH BANK OF THE MIDDLE BRANCH OF WALNUT CREEK IN THE NE. ¼ OF THE SE. ¼ OF SEC. 21, PENN TOWNSHIP.

	FEET.
(4) Grayish white limestone with some seams of shale containing *Pugnax ottumwa* White, *P. grosvenori* Hall, *Seminula trinuclea* Hall, *Spirifer keokuk* Hall, *Deltodopsis stludovici* St. J. and W. (?)	6

Sections on Rocky Branch.—On Rocky branch, which is a tributary to Walnut creek and comes in from the west, following the south boundaries of Penn and Walnut townships, rock exposures are frequent and the same succession is seen except that the lower dolomitic beds do not come into view. The sandy ledges occur farthest down and appear as far up as in the northeast quarter of section 6 in Lockridge township. The upper marls and regularly bedded limestones appear in section 36 in Penn township and in section 1 in Buchanan township. Only a few of the local details can be given.

are the result of the work of erosion performed by the present drainage. The streams have cut out and carried away the material which once filled the valleys. Their attitudes are everywhere an expression of this work, and of the conditions which have affected it. As an instance we may mention a feature, first noted and explained by Professor Calvin in other parts of the state. In creeks running from east to west the slopes on the south side descend more rapidly than the bluffs on the north side. The latter have suffered more rapid reduction owing to the more direct exposure to the sun's heat and consequent greater energy of the melted snow-water during thaws. On the slopes facing north, on the other hand, the snow melts more gradually and the slow seeping of the snow-water there has been less effective in carrying down with it the debris of the land.

The Terraces.—The work of carving out the valleys to their present depth has not proceeded at a uniform rate. At different places along the streams there are seen occasional remnants of old valley bottoms, or terraces, occupying higher levels than the present ones. The highest of these old valley bottoms in this county was first observed by Mr. Frank Leverett during his studies of the Illinoian drift. It consists of a few obscure shelves along the west bluffs of the Skunk river, in the northeast corner of the county. These have an elevation of about 125 feet above the level of the river. The best instance seen is probably on the east half of section 11 in Lockridge township, where an area of about a quarter section of the margin of the upland is some forty feet lower than the uplands to the west. This branch is believed to have been a part of the bottom of a large stream, which came down the Crooked creek valley at the time of the greatest westward extension of the Illinoian glacial lobe.* Along Cedar creek one terrace has an elevation of about eighty feet above the stream. Considerable tracts of this terrace have been preserved along its lower course in this county where the rock-bound nature of the land has prevented extensive meandering of the river. It is quite conspicuous in the south half of section 27 and in the southwest quarter of section 26, on the north side of the creek, and also in the north halves of

* Leverett; Monograph XXXVIII, U. S. Geol. Surv., p. 92.

sections 35 and 36, on the south side of the creek in Cedar township. In the adjoining south quarters of sections 33 and 34 in Round Prairie township, another quite extensive remnant follows the creek on the north side. Other instances of benches of nearly the same height occur in the west half of Locust Grove township, as in the northeast quarter of section 28 and in places in sections 21 and 20. Remnants of old bottoms rising some twenty or thirty feet above the present flood plains are more frequent. They occur on the larger as well as on the smaller streams, as may be seen along the Skunk river bluffs in section 23 in Walnut township, under the Cedar river bluffs in section 13 in Liberty township, along Brush creek in section 25, along Turkey creek in section 11 in Lockridge township, and along Walnut creek in sections 28 in Walnut and 25 in Penn townships. It may be that these terraces were made at times when the general elevation of the land was less than it is at present and thus affected the work of erosion. But another circumstance may perhaps as well have produced some of them, judging from appearances in this county. In Cedar creek the surface of the highest terrace lies only slightly above the upper surface of the bed rock, which is a solid and compact limestone, and which crosses the valley as a broad and durable sill several miles wide in the southeast part of the county. Evidently when the cutting reached this sill it was for a long time arrested, until the channel was sunk into this rock. The hard rock is many times more difficult to remove than loose drift. The creek must have established a flood plain at the level where its work was arrested by this sill and it must have spent its energy above this place in widening its valley up to the same time. The writer believes that a correct interpretation both of the age and of the causes of the terraces in this region will require a much more extensive comparative knowledge of their features than we at present possess.

The Bottom Lands.—The bottom lands, or the present flood plains, are the flat lowlands which may be inundated during high floods. Their surface lies at an elevation of from fifteen to thirty feet above the bed of the streams, and in this county from 150 feet below the upland flats nearest the larger streams

to less than seventy-five feet below the same uplands in case of the narrow alluvial tracts following the smaller divisions of their tributaries. The bottom lands of Skunk river average a little more than a mile in width, being broadest just above the mouth of Walnut creek where they reach a mile and a half from bluff to bluff. They have an elevation of about 585 feet above sea level, sloping south about two feet per mile. The flood plain of Cedar creek varies greatly in width. In Round Prairie and in the east half of Cedar township it is narrow and at times entirely absent. The stream winds along in a rocky canyon with walls from forty to seventy feet high and from a few rods to perhaps one-fourth of a mile apart. Above the mouth of Crow creek it widens out and for the next five miles maintains a width of from half a mile to a mile. Then for about three miles within the boundaries of Fairfield township it narrows to half a mile. Above this it again widens to about three-fourths of a mile and more ,in the east half of Locust Grove township. For the remaining four miles of its course in this county it is mostly less than a quarter of a mile wide. Examining the material on which the work of erosion has been performed by this stream we find that the width of its bottoms corresponds inversely to the hardness of the materials on which it has had to work. In the region of the limestone the bottoms are narrow or none. In the region where the Coal Measure shales and limestones have been worked upon the width is from one-fourth to one-half mile, and where there is only drift the bottoms widen out to as much as a mile. The elevation of the Cedar creek flood plain is about 685 feet above sea level at the west boundary of the county and about 620 feet below the mouth of Rock creek on the south boundary. The bottoms of the smaller streams, such as Walnut creek and its branches, Turkey, Brush, Wolf, Rock and Crow creeks, the two Competine creeks, Black creek and Lick creek average at least an eighth of a mile in width and sometimes expand to twice this measure, vanishing only within a mile or so of the ultimate sources of the streams. The habit of contracting in places where the channel goes below the surface of the bed rock is in their case even more conspicuous. It is universal and the writer has not observed a single exception to the rule that the bottoms are narrow in places

where outcrops of bed rock occur, and wide where the bluffs are composed of drift all the way down. The extent of the contraction of the valleys is usually proportionate to the rise of the rock. The higher this lies the more narrow the valley, and where the valleys dilate farthest it is useless to look for good exposures of the country rock.

DRAINAGE.

The drainage bears everywhere the mark of maturity and has suffered no recent changes. The larger streams probably follow drainage lines existing before the drift was laid down. The courses of the minor stream have evidently been established subsequent to the time of the ice invasions. About fifty square miles of the area of the county drain into the Des Moines system. The remaining 382 square miles belong to the Skunk river system and is divided among its several tributaries as follows:

	SQUARE MILES.
Cedar creek basin	190
Walnut creek basin	82
Brush creek basin	30
Other basins	70

The Cedar creek basin averages some twelve miles in width and extends through the south part of the county from west-northwest to east-southeast, reaching nearly to the northwest corner. Its north tributaries reach out from five to eight miles, while those on the south side drain a strip only about three or four miles wide. Most of the smaller drainage basins are likewise elongated in form and their longer axes have the same general trend. The exceptions to this rule consist of some basins which drain more nearly either north or south. These are less elongated in outline and as a consequence the branches of their creeks spread more. Such are the tributaries to the Des Moines river in the southwest part of the county and all the smaller tributaries to Cedar creek.

The land is at present almost everywhere well drained. The only exceptions consist of some few tracts of low bottom land and some shallow depressions on the widest upland flats, already referred to. Before the land was brought under cultivation these

shallow depressions on the uplands were partly filled with water after rains and this sometimes stood for an entire season. These pools were sought by the hunters, in the pioneer days, for geese and ducks. Some were conspicuous enough to receive local names. "Devil's Lake" covered at times a few acres a little east of the center of the southwest quarter of section 20 in Polk township. Other ponds occurred in the southwest quarter of section 12 and in section 13 in the same township, in the northeast quarter of section 32 in Black Hawk township, and in the southwest quarter of section 12 and the northeast quarter of section 2 in Fairfield township. At that time the uplands were less well drained than at present, and where we now find the best farms the land was at first regarded as being too wet for agricultural purposes. Most or all of the rainfall was then, as it is now, absorbed by the ground or evaporated, the surface slope being too small to drain it off, before it has time to be taken up by the porous loess soil. It escapes from there only by slow seepage and by evaporation.

TABLE OF ELEVATIONS.

STATION.	ALTITUDE.
Batavia, C., B. & Q. (new grade), b	725
Beckwith, C., B. & Q., a	777
Cedar bridge, C., B. & Q. R. R., c	702
Cedar bridge, C., R. I. & P. R. R., c	675
County Line, C., R. I. & P. R. R., c	788
Fairfield, C., B. & Q. R. R. (new grade), b	775
Glendale, C., B. & Q. R. R., a	758
Highest point C., R. I. & P. R. R., c	805
Krum, C., B. & Q. R. R. (abandoned road), a	692
Libertyville, C., R. I. & P. R. R., a	768
Lockridge, C., B. & Q. R. R., a	782
Mitchell creek bridge, C., B. & Q. R. R. (new road), b	715
Packwood B. & W. R. R., c	820
Pekin, B. & W. R. R., c	835
Perlee, C., R. I. & P. R. R. (old grade), a	679
Pleasant Plain, C., R. I. & P. R. R. (old road), a	749
Shirtz creek bridge, C., B. & Q. R. R. (new road), b	720
Skunk river, near Coppock, c	570
Upland west of Batavia, c	790
Veo, B. & W. R. R., c	790
Woolson, B. & W. R. R., c	784

Authority: (a) Gannett's Dictionary of Altitudes in U. S.; (b) Engineer's office, C., B. & Q. R. R.; (c) Aneroid measurements by the author.

STRATIGRAPHY.

General Relations of Strata.

In the west half of the north tier of townships the streams have not cut through the drift and no rock exposures have been observed. The thickness of the drift appears to be quite uniform, some 125 feet, although one well record gives 180 feet. Immediately under this lie the Coal Measures, averaging perhaps fifty feet in depth. These have been quite extensively removed on the lowlands, however, and in the northeast part of the county they are absent even on the uplands. The Coal Measures in turn rest on the Saint Louis limestones, shales and sandstones, which belong to the Lower Carboniferous and which average about one hundred feet in depth. The following table will further elucidate the general arrangement of these divisions:

GROUP.	SYSTEM.	SERIES.	STAGE.	SUB-STAGE.
Cenozoic.	Pleistocene.	Recent.	Alluvial and terrace.	
		Post-Kansan.	Loess.	
		Glacial.	Kansan	
			Aftonian.	
			Albertan.	
Palæozoic.	Carboniferous.	Upper Carboniferous.	Des Moines.	
		Lower Carboniferous.	Saint Louis.	Pella.
				Verdi.
				Springvale.

Underlying Formations.—Under the rock seen in the lowermost exposures there is some thirty feet of limestone, with some shale and sandstone, as is shown in the deep well at Ottumwa and also known from exposures in the counties of the east. This is mainly the Augusta limestone, also known as the Keokuk and the Burlington. Below this the Kinderhook shales continue for some 150 feet, under which there is nearly 500 feet of limestone with some included shale. Then the Saint Peter sandstone follows, about 100 feet in thickness, and limestone with some shale run on for 900 feet below this, which is the greatest depth reached by explorations in this region.*

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8. (2)	Yellow, marly, dolomitic material	5
7. (2)	Yellow, wavy-bedded mortar-rock with a pure calcareous, and slightly porous matrix, making more than half of the bulk of the rock and being in places without sand. The imbedded rounded sand grains averaging somewhat less than one millimeter in diameter in all samples examined, but range up to five times this size. The largest of the siliceous fragments are angular and consist of chert	4
6. (2)	Yellow, mortar-rock, with a pure calcareous and slightly porous matrix. The sand constitutes about one-half of the bulk of the rock, and consists of rounded grains of quartz averaging less than one millimeter in diameter, and ranging up to two millimeters. There are also fragments of chert from one-half to three centimeters in diameter. These have their surfaces frequently marked by shallow concave hollows, apparently produced by etching, as by solution. Yet the texture of the bed is very variable. In places it is traversed by thin, long and curving fissures which are filled with clear calcite	⅔
5.	A band of yellowish gray chert of rather even thickness	¼
4. (1)	Yellow or blue, marly, magnesian limestone with band of chert. A hand specimen was observed to be without any sand. It had minute porosities, apparently due to the removal of some organic fragments. Some of these were minute, straight, tubules. Imprints of a Productus were noted	3½

		FEET.
3.	(1) Yellow and somewhat indurated magnesian limestone	⅓
2.	(1) Greenish gray, shaly marl with irregular loaf-shaped concretions of tough, gray quartz..	3
1.	(1) Fine-grained, almost compact and partly dolomitic limestone of yellow color and with streaks of imbedded fine sand. On fresh fractures there were seen minute, dark, dendritic blotches as of manganese oxide. The ledge is traversed by thin curving fissures, which are healed mostly with a dark ferruginous cement. Seen in bed of the creek to a depth of about.............	1

II. SECTION IN THE WEST BANK OF BURR OAK CREEK, NEAR THE CENTER OF THE SW. ¼ OF THE SW. ¼ OF SEC. 26, WALNUT TOWNSHIP.

		FEET.
5.	(1) Dull yellow, magnesian limestone	1½
4.	(1) Yellow dolomitic marl	5
3.	(1) Yellow, apparently leached and somewhat dolomitic limestone of fine texture containing fragments of a Productus and Fenestella	¼
2.	(1) Dull yellow marl, somewhat dolomitic	3
1.	(1) Greenish, slightly calcareous shale containing irregular shaped, loaf-like concretions of a tough gray quartz, somewhat resembling geodes, but differing from these in always having a solid center and in showing no crystals	3

Sections on Walnut Creek.—Following Walnut creek we find the same succession. The lowest rock exposed in the bed of this creek, about one-fourth of a mile west of the center of section 2, Lockridge township, is identical with number 4 in section 1 above, except that it is slightly less dolomitic and that it contains occasional small kernels, or lumps, of compact calcareous material, as if the process of dolomitization were less far advanced. Along the bend to the south which this stream makes in sections 2 and 3 these dolomitic beds are exposed, and above them we find sandy, cross-bedded limestones rising thirty or forty feet. These continue for four miles above and are in turn overlain by brecciated, more calcareous and less sandy limestone ledges, as may be seen in sections 19, 20 and 29 in Walnut township, and in sec-

tions 24, 25 and 26 in Penn township. Still farther up, as in sections 21, 23, 26 and 27, yet higher beds occur above these, in the banks of the main creek and its forks and these consist of quite evenly bedded gray limestones and marls. The cross-bedded sandy rock is particularly well exposed in the right bank of the creek along the east line of the northeast quarter of section 29 in Walnut township. The relation and characteristics of the different divisions are well represented in the following sections:

III. SECTION IN A RAVINE AND IN A STONE QUARRY IN THE SW. ¼ OF THE SE. ¼ OF SEC. 3, LOCKRIDGE TOWNSHIP.

	FEET.
5. (3) White, weathered limestone-breccia, weathering into angular fragments. Some of this breccia is arenaceous, with imbedded pieces of pure white limestone. Occasionally an almost pure sand fills the interstices between the blocks and fragments of the breccia. (Seen above the stone quarry.)	5
4. (3) Yellow clay and marl	3½
3. (2) Porous limestone of dark gray color. It contains occasional nodules of chalcedonic quartz. In some places it gives a faint bituminous odor, when struck by the hammer. It contains a small and variable amount of well rounded sand grains and also of calcareous fragments of a different and finer texture from that of the main matrix. In places the rock contains scattered clear crystals of calcite measuring about one-eighth of an inch in length. These are occasionally dissolved out leaving small cavities. Some of the larger quartz sand grains and small pebbles, which this rock contains, have shallow, concave depressions on the surface. These have apparently been produced by solvent action of the ground water. In three rock specimens, carefully examined, different stages of this etching were noticed. Its extreme result is the production of a porous, calcareous rock with only a few imbedded, angular, siliceous particles. (The main quarry rock in Walgren's quarry)	7
2. (2) Porous, grayish yellow limestone, somewhat irregularly bedded, and considerably af-	

	FEET.
fected by weathering and leaching (exposed below the quarry)	5
1. (1) Dolomitic marl, almost stony above and more shaly below. When crushed and examined under the microscope the marly material is seen to consist of very small rhombohedral crystals, which effervesce tardily in moderately strong acids. (Exposed in a ravine below the quarry.)	8

IV. SECTION IN THE LEFT BANK OF WALNUT CREEK, ABOUT TWENTY RODS SOUTHEAST OF THE CENTER OF THE SW. ¼ OF SEC. 20, WALNUT TOWNSHIP.

	FEET.
2. (3 & 4) Gray, partly brecciated limestone (not well exposed)	20
1. (2) Sandstone and arenaceous limestone, frequently cross-bedded	25

V. SECTION IN THE SOUTH BANK OF WALNUT CREEK, ABOUT ONE FIFTH OF A MILE WEST OF THE EAST LINE OF SEC. 19, WALNUT TOWNSHIP.

	FEET.
3. (4) Gray, hard limestone, slightly brecciated and broken, and with some thin seams of marl between some of the ledges	10
2. (3) A stony marl containing a small and almost spherical Seminula in abundance, and lumps of concretionary limestone, and of oolitic limestone. The oolitic spherules average one half of a millimeter in diameter and are mingled with occasional larger lumps of compact limestone. Most of them are elliptical in cross section and consist of a dark central plate which is surrounded by a light-colored thick envelope, which again is surrounded by a thin crust of dark color on the outside	⅓
1. (3) Flexed, faulted and brecciated ledges of hard gray limestone	10

VI. SECTION IN THE NORTH BANK OF WALNUT CREEK, AT THE SOUTHEAST CORNER OF SEC. 24, PENN TOWNSHIP.

	FEET.
(2) Slanting and cross-bedded ledges of limestone alternating with more massive ledges of mortar-rock. The latter is in places seen to have promiscuously arranged, curving, tubular cavities of variable diameter, which are	

	FEET.
filled with calcite. The mortar-rock consists of a calcareous matrix making from ten per cent to forty per cent of the bulk, and containing imbedded well-rounded sand grains, the prevailing size of which in one hand specimen was from one-third to one-fourth of a millimeter in diameter. In same specimen ninety-eight per cent of the grains consisted of white quartz. The remainder consisted or quartz of an amethyst pink color, bright green grains, and some dark quartz. Some spherical grains of lime carbonate were also observed, and resembled oolotic spherules	12

VII. SECTION IN THE SOUTH BLUFF OF THE NORTH BRANCH OF WALNUT CREEK NEAR THE SOUTHWEST CORNER OF SEC. 23, PENN TOWNSHIP.

	FEET.	INCHES.
3. (4) Grayish white limestone in thin ledges......	3	
2. (4) Grayish white limestone in a single solid ledge, with curving flattened stems resembling fucoids impressed into the upper surface. It contains, especially near its lower surface, *Pugnax ottumwa* White, *Seminula trinuclea* Hall, and *Spirifer keokuk* Hall.	2½	
1. (4) A thin seam of shaly material containing *Pugnax ottumwa* White, in abundance....		½

VIII. SECTION IN THE NORTH BANK OF THE MIDDLE BRANCH OF WALNUT CREEK IN THE NE. ¼ OF THE SE. ¼ OF SEC. 21, PENN TOWNSHIP.

	FEET.
(4) Grayish white limestone with some seams of shale containing *Pugnax ottumwa* White, *P. grosvenori* Hall, *Seminula trinuclea* Hall, *Spirifer keokuk* Hall, *Deltodopsis stludovici* St. J. and W. (?)	6

Sections on Rocky Branch.—On Rocky branch, which is a tributary to Walnut creek and comes in from the west, following the south boundaries of Penn and Walnut townships, rock exposures are frequent and the same succession is seen except that the lower dolomitic beds do not come into view. The sandy ledges occur farthest down and appear as far up as in the northeast quarter of section 6 in Lockridge township. The upper marls and regularly bedded limestones appear in section 36 in Penn township and in section 1 in Buchanan township. Only a few of the local details can be given.

IX. SECTION IN THE SOUTH BLUFF OF ROCKY BRANCH, IN THE NW. ¼ OF THE NW. ¼ OF SEC. 3, LOCKRIDGE TOWNSHIP.

	FEET.
4. (3) White, somewhat brecciated limestone with cakes of yellow chert (not well exposed)..	5
3. (3) Marly band with a small and almost spheroidal Seminula	½
2. (3) Brecciated, light-colored limestone (imperfectly exposed)	6
1. (2) Cross-bedded and variable mortar-rock and limestone	30

X. SECTION IN THE BED OF A RAVINE GOING SOUTH INTO ROCKY BRANCH IN THE SW. ¼ OF THE SE. ¼ OF SEC. 32, WALNUT TOWNSHIP.

	FEET.
4. (?) Brecciated white limestone in a solid ledge, which is fossiliferous below...............	3
3. (3) Greenish marl with fossils which are deformed, mostly Pugnax	½
2. Concealed	2
1. (2 and 3) Laminated sandstone changing into limestone above	2½

XI. SECTION UNDER THE BASE OF THE WEST BLUFF OF A SOUTH TRIBUTARY TO ROCKY BRANCH IN THE NE. ¼ OF THE NW. ¼ OF SEC. 8, LOCKRIDGE TOWNSHIP. [MONSON'S QUARRY.]

	FEET.
5. (3 or 4) Fine-grained, compact limestone of almost lithographic texture, and containing small spherical aggregarates of pyrites..	1⅓
4. (3 or 4) Soft, gray limestone in thin courses...	2
3. (3 or 4) Gray limestone in a single ledge........	2¼
2. (3) Dark gray, compact and slightly bituminous limestone, which is unequally affected by acids taken from different spots, being dolomitic in some places and calcareous elsewhere. A hand specimen was seen to be made up of a compact aggregate of somewhat obscurely limited, fine particles of varied shape, some being organic fragments and some appearing like accretions of a calcareous precipitate	½
1. (3) Blue shaly marl, exposed	¼

Sections on Turkey Creek and adjacent Ravines.—In the northeastern part of Lockridge township the Saint Louis rocks have their greatest vertical development in this county. This region drains into Skunk river, whose channel lies nearly 200 feet below the highest adjacent uplands, and the smaller streams afford several deep and comparatively narrow valleys exposing the bed

rock. In "Cedar Bluff," on the west bank of Skunk river and at the north line of section 13 in Lockridge township, all the divisions in the preceding sections, except the uppermost, appear in succession. They show the effects of weathering and of leaching by the underground water. Occasionally there are indications of small, ancient cavernous openings which have been partly filled and collapsed, causing local brecciation. In a small ravine in the southeast quarter of section 24 in Lockridge township two large crystalline masses of Iceland spar lay near a small exposure of limestone, in which several fissures filled with the same mineral were noted. One of these masses was sixteen inches in diameter. The following sections are typical of the region:

XII. SECTION IN P. W. LYON'S QUARRY IN THE NORTH BANK OF TURKEY CREEK NEAR THE CENTER OF THE NE. ¼ OF SEC. 11, LOCKRIDGE TOWNSHIP.

	FEET.
9. (3) Compact, grayish white limestone, considerably weathered	1
8. (3) Yellowish gray marl, with more solid calcareous lumps	2
7. (3) Greenish shale	1½
6. (3) Breccia of sandy, yellow marl with angular lumps of limestone of fine lithographic texture and round concretions of less fine texture. This breccia is overlain by a continuous layer of laminated limestone. The round concretions have a brecciated structure, showing fragments of varied texture and some fine branching joints, which have been healed by infiltration. The laminated layer which overlies contains a very few small grains of quartz and is itself composed of an aggregation of small grains or lumps or compact calcareous material. These lie closely appressed and are in some places flattened, as if by pressure in a vertical direction. Some minute stylolithic joints are seen, and there are a few very small imbedded shells of a brachiopod	5
5. (3) Greenish gray clay	2
4. (2) Yellow limestone	1
3. (2) Greenish, shaly marl	¼
2. (2) Mortar-rock, changing downward into a more pure sandstone. The upper part is brownish in color and the cement in	

		FEET.
	which the sand lies is partly dolomitic. In one hand specimen, which was carefully examined the quartz grains were from one-eighth to two millimeters in diameter. The grains exceeding one millimeter were very generally rounded, while those below this size were mostly angular. Mica occurred sparsely. Joints of crinoid stems and some tubes of a bryozoan were noted. Another specimen from the base of this ledge was a fine-grained and friable sandstone with a sparse and wholly dolomitic cementing matrix. The sand grains were mostly from one-half to one-fourth millimeters in diameter. Mica was present, but sparse	5
1. (2)	Obliquely bedded mortar-rock consisting of about one-third of its bulk of arenaceous material, with occasional lumps of clay and with some interbedded thin seams of bare matrix without sand. The bulk of the sand in one hand specimen, consisted of grains from one-fourth to one-half millimeters in diameter, quite generally rounded. The material represented was in the main translucent quartz. Some of the grains were light colored and dark chert, and a few mica quartz scales. Joints of crinoid stems and tubes of some bryozoa were also found. The cementing material was seen to be of variable abundance along different bedding planes, and some of it effervesced readily and some tardily under the action of acids. The slow effervescence was particularly noticeable along some bluish gray and compact layers, which were interlaminated with the otherwise porous and coarse-textured bulk of the rock. The surface of this ledge was covered with a white efflorescence of magnesium sulphate......	11

XIII. SECTION IN THE SOUTH BANK OF TURKEY CREEK, THIRTY RODS NORTHWEST OF THE SOUTHWEST CORNER OF SEC. 10, LOCKRIDGE TOWNSHIP.

		FEET.
3. (4)	Gray limestone	1½
2. (3)	Shaly marl with Seminula	½
1. (3)	Limestone, marly below	4½

XIV. SECTION IN "CEDAR BLUFF" AT THE MOUTH OF RATTLESNAKE CREEK, ONE-FOURTH MILE EAST OF THE SOUTHWEST CORNER OF SEC. 12, LOCKRIDGE TOWNSHIP.

		FEET.
22.	(4) Somewhat brecciated but otherwise compact grayish white limestone	2
21.	(4) Green shaly material	1
20.	(4) Brecciated gray limestone	1
19.	(4) Thinly laminated stony calcareous material	1/3
18.	(4) Brecciated and in part laminated gray limestone	2½
17.	(4) Seam of shaly material	¼
16.	(4) Brecciated gray limestone	1¼
15.	(3) Shaly marl with some concretions of calcareous material and a small, almost spherical form of Seminula	½
14.	(3) White, incipiently brecciated limestone, with stylolithic joints along some seams A hand specimen was seen to be a compact rock filled with minute organic fragments mostly so small as to fall short of observation by the unaided eye. It also contained occasional minute oolitic spherules	6
13.	(3) Dull grayish yellow limestone	2
12.	(3) Yellow shaly marl	5
11.	(3) Massive beds of soft, earthy, greenish limestone weathering into spheroidal masses with more thoroughly weathered material between. A hand specimen was seen to be of a fine and uniform texture, with some faintly marked bedding planes. When crushed and examined under the microscope the almost entire mass was seen to consist of exceedingly small rhombohedral crystals, which effervesced slowly with acids (dolomite)	3
10.	(3) Same as above, but more soft	2
9.	(3) Soft and earthy mortar-rock, consisting of about one-half sand and the other half being a calcareous magnesian matrix. The bulk of the sand grains are from one-fourth to one-half of a millimeter in diameter, but range up to one millimeter. The finest sand is mostly angular but the coarse grains are well rounded	3
8.	(3) Shaly marl, containing fragments and lumps of limestone	4
7.	(2) Grayish yellow and soft dolomitic rock with an irregular bedding of a concretionary	

		FEET.
3.	(4) Gray limestone in sound ledges, containing frequent cubic crystals of pyrites	2
2.	(4) Gray limestone with the upper surface of the ledge bearing occasional fucoid flattened curving stems some six inches in length and an inch in widest diameter...	1
1.	(4) Gray limestone with upper surface of the ledge frequently studded with such fossils as *Spirifer keokuk* Hall, *Pugnax ottumwa* White *Allorisma*, sp., *Productus*, sp. and stems of crinoids	

About a quarter of a mile farther up this creek the underlying sandy ledges are seen in the left bank, and above this place the fossil-bearing limestone ledges are again exposed at intervals, disappearing under the drift about half a mile from the east boundary of the county. Above this place only two small and widely separated occurrences of the Saint Louis beds were observed in this stream. One of these has been quarried. It is located in the northeast quarter of the northwest quarter of section 28 in Lockridge township. The other locality is in the south bank of the creek in the west half of the southeast quarter of section 10 in Buchanan township. In both of these places the ledges which are exposed belong to the upper fossil-bearing division of this formation.

On Wolf creek only one exposure was noted, and this was quite small and belonged to the same horizon, as seen from the following:

XVIII SECTION IN THE BED OF WOLF CREEK, SOUTH OF THE CENTER OF SEC- 5, ROUND PRAIRIE TOWNSHIP.

		FEET.
2.	(4) Light gray marl with joints of crinoid stems, lamellibranchs, small cyathophylloids, *Anisotrypa fistulata* Uhlr., *Fenestella serratula* Uhlr., *Phillipsia* (?*pygidium*), *Eumetria marcyi* Shumard, *Derbya keokuk* Hall, *Pentremites koninkiana* Hall, *Productus ovatus* Hall, *Seminula trinuclea* Hall, *Pugnax ottumwa* White, *P. grosvenori* Hall, *Cleiothyris roissyi* L'Eveille, *Spirifer keokuk* Hall, *Dielasma formosa* Hall, *Pinna* (? fragment)	5
1.	(4) Gray limestone with some fossils	2

Sections in the Cedar Creek Basin.—In the drainage basin of Cedar creek the Saint Louis is best exposed on the main stream. A thickness of nearly sixty feet can be made out and this includes the two upper divisions seen in the Skunk river drainage basin. From south of the center of section 35 in Round Prairie township to the west line of section 36 in Cedar township the outcrops are almost continuous in the banks of the Cedar creek, and after an interruption of one-half a mile of Coal Measure rocks it continues two and a half miles farther up the creek. Above this there are only two other points at which it rises above the creek, one in the northeast quarter of section 24 and another somewhat larger area in sections 9, 10 and 15 in Liberty township. West of here it has not been observed. Most of the tributaries from the south in Cedar and Round Prairie townships cut down into this limestone as far as their courses run in this county, but in the affluents from the north it is seen only in Rock creek, where it appears for two miles. The following sections will sufficiently illustrate its character in this region:

XIX. SECTION IN THE BANK OF CEDAR CREEK IN THE SW. ¼ OF THE SE. ¼ OF SEC. 34, ROUND PRAIRIE TOWNSHIP.

	FEET.
5. (4) Gray marl containing *Pugnax ottumwa* White, *Productus* sp., *Seminula trinuclea* Hall, and some rhizopods	2
4. (4) White limestone with one ledge of very fine, almost lithographic texture. A ground specimen of the latter was seen to contain scattered imbedded fragments of small brachiopods and dispersed minute crystals of pyrites	2
3. (4) Gray limestone of ordinary texture, in ledges varying from six inches to one foot in thickness. A shaly seam near the middle was studded with *Pugnax ottumwa* White	5
2. Not seen here. (What follows is exposed about fifteen rods farther south in the bed and the banks of the "cut-off" which the creek is making in leaving the oxbow)	30(?)
1. (3) Gray, arenaceous limestone changing downward into softer, yellow, dolomitic rock. The ledges are flexed and fractured and in places brecciated. In the middle part of the exposure there is a discontinuous	

	FEET.
layer of breccia, about a foot thick, which is partly silicified and has a very rough exterior. At about the same level silicified specimens of *Lithostrotion canadense* Cast. occur and below this the rock contains smooth loaves and balls of a yellow or gray chert, which contains frequent casts of brachiopods, such as *Derbya keokuk* Hall, *Spirifer littoni* Swallow and *Pugnax grosvenori* Hall. Associated with these chert balls and also occurring in small crevices in the surrounding rock is a dark green earthy clay containing aluminum, iron, and a trace of chromium. The same ledges have crevices which contain some very clear crystals of Iceland spar. These are stained green by the same earthy material. One fractured ledge in the lower part of the exposure consists of a fine-textured and minutely porous limestone which contains indistinct fragments of shells. This is cut by some very thin fissures filled with limonite	10

XX. SECTION IN THE NORTH BANK OF CEDAR CREEK, EAST OF THE SOUTHWEST CORNER OF SEC. 34, ROUND PRAIRIE TOWNSHIP,

	FEET.
6. (3 and 4 ?) Solid ledges of gray, partly brecciated limestone with some layers of shaly marl	20
5. (3) Marly dolomitic material	3
4. (3) A more or less discontinuous ledge of cherty gray or dark quartz showing a peculiar brecciated structure	2
3. (3) Yellow or gray, soft limestone, occasionally dolomitic and often with some imbedded sand and lumps of brecciated siliceous material. In places it is coarsely brecciated and in other places it contains thin layers of fine-textured dolomitic rock with minute lentils of *Lithostrotion canadense* Cast.	5
2. (3) Pure calcareous limestone with a Seminula and occasional balls or loaves of chert with casts of other brachiopods. Some small fissures in this ledge, evidently due to incipient brecciation, were observed to be filled with arenaceous material	1½

	FEET.
1. (3) Light gray, greenish marly shale with thin layers of pure calcareous rock. Other layers are slightly dolomitic and are in places cut by very thin fissures healed with crystalline calcite	4

XXI. SECTION IN THE SOUTH BANK OF ROCK CREEK IN THE NE. ¼ OF THE NE. ¼ OF SEC. 32, ROUND PRAIRIE TOWNSHIP.

	FEET.
10. (4) Gray marl	⅓
9. (4) Limestone	½
8. (4) Gray marl	½
7. (4) Limestone	1½
6. (4) Marl	⅛
5. (4) Limestone	1
4. (4) Yellow marl containing *Productus ovatus* Hall, *Productus marginicinctus* Prout, *Pugnax ottumwa* White, *Spirifer keokuk* Hall, *Seminula trinuclea* Hall (?), *Fenestella serratula* Uhlr., *Anisotrypa fistulata* Uhlr., cyathophylloids and stems of crinoids	5
3. (4) Limestone	1
2. (4) Marl with some of the same fossils as those above	⅛
1. (4) Quite evenly bedded ledges of bluish gray limestone	7½

XXII. SECTION IN A RAVINE ABOUT ONE-SIXTH MILE SOUTHWEST OF THE CENTER OF SEC. 23, ROUND PRAIRIE TOWNSHIP.

	FEET.
6. (4) Solid grayish white limestone on the upper surface of which were noted *Pugnax ottumwa* White, *Spirifer littoni* Swallow, *Dielasma formosa* Hall, *D. turgida* Hall, and a small lamellibranch	5
5. (3) Shaly and impure limestone..................	5
4. (3) Limestone disintegrating into hard and thin layers	4½
3. (3) Arenaceous shale	2
2. (3) Irreguarly bedded gray or blue soft rock....	4
1. (2) Cross-bedded mortar-rock with some shaly beds	20

XXIII. SECTION IN THE SOUTH BANK OF CEDAR CREEK IN THE NE. ¼ OF SEC. 34, CEDAR TOWNSHIP.

	Feet.	Inches.
5. (4) Grayish white limestone	4	
4. (4) Marly limestone with two bands of more solid stony material near the middle. This contained *Productus marginicinctus* Prout., *P. ovatus* Hall, *Pugnax ottumwa* White, *Spirifer keokuk* Hall, *Seminula trinuclea* Hall, *Zaphrentis pallaensis* Worthen, *Anisotrypa fistulata* Uhlr., and *Allorisma marionensis* White	4	
3. (4) Band of limestone		7
2. (4) Seam of shale sharply marked off above and below		4
1. (4) Grayish white limestone, the upper ledges having a fine texture and being bedded in straight courses of uniform thickness	6½	

XXIV. SECTION IN AN OLD QUARRY IN THE EAST BANK OF CEDAR CREEK NORTHEAST OF THE CENTER OF SEC. 10, LIBERTY TOWNSHIP.

	Feet.	Inches.
6. Pockets of green shale belonging to the Coal Measures.		
5. (4) Gray limestone weathering into round bowlders, in places with small crevices filled with calcite. Fragments of crinoid stems and brachiopod shells are common	4	
4. (4) Light-colored marl with occasional stony concretions. This marl contains *Cleiothyris roissyi* L'Eveille, *Derbya keokuk* Hall, *Productus ovatus* Hall, *P. marginicintus* Prout., *Seminula trinuclea* Hall, *Spirifer keokuk* Hall, *Lithophaga pertenuis* M. & W. (?), various small cyathophylloids, stems of crinoids, small plates of an Archæocidaris, *Endothyra baileyi* Hall, *Cytherellina glandella* Whitfield, *Leperditia carbonaria* Hall and minute calcareous spines of various forms	2	
3. (4) Gray limestone		8
2. (4) Marl with most of the same fossils as were found in number 4	3	
1. (4) Gray limestone containing occasional crystals of pyrites	3	

XXV. SECTION NEAR THE CHICAGO, ROCK ISLAND & PACIFIC RAILROAD IN THE NW. ¼ OF THE SE. ¼ OF SEC. 9, LIBERTY TOWNSHIP.

		FEET.
2. (4)	Grayish white marl containing many fossils such as *Cleiothyris roissyi* L'Eveille, *Derbya keokuk* Hall (?), *Productus ovatus* Hall, *Pugnax ottumwa* White, *P. grosvenori* Hall, *Seminula trinuclea* Hall, *Spirifer keokuk* Hall, *Allorisma marionensis* White, some cyathophylloids, some bryozoa, stems of crinoids, and some rhizopods	4
1. (4)	Grayish white limestone in heavy ledges, containing some of the same fossils that were found in the marl above. A polished hand specimen was seen to have occasional small crevices filled with calcite. There were also frequent imbedded fragments of stems of crinoids and shells of brachiopods. When crushed and washed it yielded some shells of rhizopods	4

Sections in the Des Moines River Basin.—In the drainage area of the Des Moines there are also a few places where the deepest valleys have laid bare the Saint Louis. These are in Lick creek at and near the junction of its two forks in section 30, Liberty township. Farthest south there are some brecciated and slightly arenaceous limestones and to the north of this place to the more regular bedded limestone with alternating layers of marl. We have here the same succession and no doubt the same beds as seen on Cedar creek. In the southwest quarter of the southeast quarter of section 30 an open well was in the process of being blasted out in this formation at the time of the survey. It was in the valley of the creek close to the south bluff and showed twenty feet of limestone alternating with some fine arenaceous beds below and some shale above. The natural exposures were as follows:

XXVI. IN THE BED OF LICK CREEK NEAR THE CENTER OF SEC. 25, DES MOINES TOWNSHIP.

		FEET.
2. (4)	Stony marl containing *Seminula trinuclea* Hall, *Pugnax ottumwa* White, *Productus* sp., *Pinna* (?) (fragment), *Astartella* sp.. (?)	1
1. (4)	Solid gray limestone with some fossils	2

XXVII. SECTION IN THE WEST BANK OF THE EAST FORK OF LICK CREEK IN THE NW. ¼ OF THE SE. ¼ OF SEC. 30, LIBERTY TOWNSHIP.

	FEET.
6. (4) Gray limestone	1
5. (4) Gray marl with some fossils	2
4. (4) Gray limestone	2
3. (4) Gray marl with occasional fossils	2
2. (4) Heavy ledges of gray limestone	4
1. (3) Limestone, occasionally brecciated	9

STRATIGRAPHY.

In the foregoing sections an attempt has been made to refer the respective numbers which have been described to one of the four divisions into which the Saint Louis strata can be divided in this region. These divisions have been indicated for each member by figures in brackets. They correspond, in the main, to the divisions previously made out for the Saint Louis in Washington county by Bain, and which will here be designated by names essentially as proposed by him, viz:

	APPROXIMATE THICKNESS IN FEET.
(4) Pella beds	17
(3) Upper Verdi beds	30
(2) Lower Verdi beds	30
(1) Springvale beds	18
Total	95

The Verdi beds have been separated into an upper and a lower division. It is quite probable that neither the lowermost part of the Springvale beds, which make the base of the section, nor the uppermost part of the Upper Pella beds, which constitutes the top of the formation, are seen in this county. It is therefore likely that the Saint Louis exceeds in thickness the ninety-five feet which appear in this county. A brief general description may now be given of each of the four divisions.

The Springvale Beds.—These consist of soft dolomitic limestones interbedded with dolomitic marly shales and some sandstone of fine texture. The dolomite consists of an aggregate of crystals of minute but varying sizes. It frequently contains small lentils of green clayey material, is here and there traversed by thin and curving fractures which have been filled with clear crystalline calcite and occasionally contains a small admixture

of fine sand. With the aid of a hand lens some minute straight tubules are commonly seen in these ledges. The shaly beds are often marly and dolomitic. Some are apparently disintegrated and leached dolomite. The more clayey beds contain solid spheroidal concretions of chalcedonic quartz, measuring from two to eight inches in diameter and resembling geodes in form. In the limestones, impressions or imperfectly preserved fossil remains were noted representing stems of crinoids, a species of a Productus, and *Hemitrypa frontana* Uhlr.

The Lower Verdi Beds.—Above the magnesian limestones and shales just described, there is usually some exceedingly variable material most of which might be called mortar-rock as it consists of sand cemented together by a calcareous or magnesian matrix. The sand may be fine or coarse, the matrix may be calcareous or dolomitic, and the ratio between the sand and the matrix may vary to the exclusion of either one of the two, when there is pure sandstone on the one hand, and pure limestone on the other. By the increase of clayey material either of these rock varieties may become shaly. The limestones are hard and compact, or marly. The mortar-rock and the sandstones may be regularly bedded, or they may be most diversely cross-bedded. Frequently the alternating thin seams have an unequal amount of matrix and sand. Finally, any of these variations and sediments may be brecciated and mingled with each other promiscuously. Dolomitic layers are apt to exhibit occasional thin fissures filled with crystalline calcite. The arenaceous material ranges in the sizes of the grains from pebbles half an inch in diameter, which are rare, to the finest discernible particles. It is usually well sorted for each layer, and all the medium sized grains are well rounded. Ninety-five per cent, if not more, consist of clear white quartz. The remainder is mica, a few pink, purple, and green grains among the finest materials, and some chert and some calcareous fragments among the largest pebbles. At one place there was seen in a coarse and very sandy mortar-rock of this division some curving tubular cavities in the sand (section VI). These are filled with calcite so as to make the rock perfectly compact and they presented an appearance which suggested an organic agency, as if produced by some boring animal. At several other places there

were noted small and single joints of crinoid stems. A bryozoan or a coral, somewhat like a Monticutipora and consisting of closely appressed and nearly parallel tubes, which were quite fragile and poorly preserved, was seen in several places in the mortar-rock, associated with crinoid joints.

The Upper Verdi Beds.—The arenaceous members just described change upward into brecciated, less sandy, and less frequently dolomitic limestone. At this horizon there are some very fine-grained calcareous ledges, in which lie imbedded fragments of thin brachiopod shells, and occasional oolitic spherules. The siliceous material is often gathered into concretionary masses, sometimes of great size. There are silicified corals, and nodules of chert containing moulds of brachiopod shells. In the valley of Cedar creek large lenses of a tough gray or almost black quartz of a peculiar brecciated structure, as if deposited by infiltration along closely intersecting joints, are seen replacing parts of certain ledges (Fig. 60). One of these masses was six feet wide and two feet thick near the middle, having a hemispherical shape with the convex side up. Several fossils occur at this horizon, viz:

Lithostrotion canadense, Cast. (usually though not always, silicified. Seen *in situ*).
Derbya keokuk Hall (moulds in chert nodules).
Pugnax grosvenori Hall (large, moulds in chert.)
Seminula sp.
Spirifer keokuk Hall (in chert).
Leperditia carbonaria Hall (large and black).
Ganoid? (plate-like scales).

In the creeks draining into Skunk river there occurs near the top of this division a shaly or marly seam, usually about six inches in thickness, which can be recognized at points several miles apart. It lies between two ledges of solid limestone, which are sometimes slightly broken or brecciated. In correlating local sections this seam serves as an important landmark, and therefore deserves special attention here. It is number 2 of section V, number 3 of section IX, number 2 of section XIII, number 15 of section XIV, and number 2 of section XVI. It is also seen east of the wagon road in the north bluff of Rocky branch near the northwest corner of section 3, Lockridge township, and near a

spring west of the wagon road in a small tributary to Walnut creek from the north, near the center of the southwest quarter of the southwest quarter of section 21, Walnut township. This layer contains invariably and in profusion a Seminula with very convex valves and of small size, so as to be of the size and shape of a pea. The valves are frequently dissolved away, leaving a mere

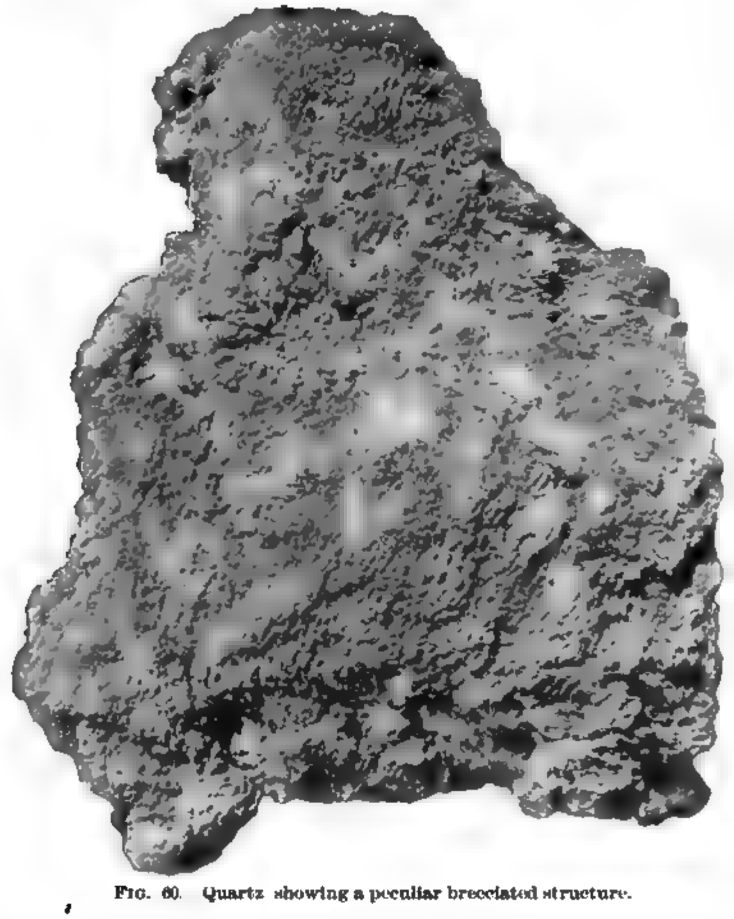


FIG. 60. Quartz showing a peculiar brecciated structure.

calcareous kernel, in which the spirals of the fossil sometimes appear. At other places these shells may be covered by an enveloping calcareous crust, and simulate roughly shaped pisolitbs. Associated with these shells there are calcareous concretions or balls, usually slightly flattened and about an inch in diam-

eter. In the interior of these there are irregular pockets of a white calcareous flour. The seam may be said to consist of these concretions and of the small Seminula shells, imbeddeed in a shaly or marly sparse matrix. On the surface of one of these concretions were noted some minute brachiopods and *Leperditia carbonaria* Hall. Occasionally a part of the bed consists of lumps of fine oolitic limestone. The Seminula is regarded by Schuchert as being an undetermined species different from *Seminula trinuclea* Hall, which occurs in the Pella beds farther up in the section. In several places springs issue from the ground two or three feet below this shaly seam.

The Pella Beds.—These consist mostly of heavy-bedded ledges of compact, calcareous limestone, alternating, especially above, with seams of greenish marly shales. Occasionally the limestone is slightly broken up and brecciated. Some ledges have a very fine texture. Were it not for the presence of bits of fossils, and crystals or irregularly shaped grains of pyrites these ledges might be called lithographic limestone. The pyrites is usually in cubic crystals, about an eighth of an inch in diameter. The shales or marls are sometimes quite hard and stony. Fossils are common in the limestones and quite abundant in the marls, consisting of a few species of brachiopods, lamellibranchs, cyathphylloids, bryozoa, ostracods and rhizopods. The latter occur both in the limestone and in the marls. A list of the fossils observed by the author is here given. The appended figures indicate the number of localities at which each species has been noted.

Endothyra baileyi Hall, 5.
Other rhizopods, not identified, 4.
Zaphrentis pellaensis Worthen, 8.
Pentremites koninckiana Hall, 1.
Archaeocidaris (spines and separate plates, small), 2.
Crinoids (stems), 10.
Spirorbis (?), 1.
Anisotrypa fistulosa Uhlr., 6.
Fenestella serratula Uhlr., 3.
Cleiothyris roissyi L'Eveille, 8.
Derbya keokuk Hall, 4.
Dielasma formosa Hall, 2.
Dielasma turgida Hall, 1.
Eumetria marcyi Schumard, 1.
Productus marginicinctus Prout, 3.
Productus ovatus Hall, 6.

Pugnax grosvenori Hall, 4.
Pugnax ottumwa White, 13.
Seminula trinuclea Hall, 8.
Seminula sp. undet. 7.
Spirifer keokuk Hall, 7.
Allorisma marionensis White, 3.
Astartella sp., 1.
Lithophaga pertenuis M. & W. (?), 2.
Pinna ? (fragment.) 1.
Cytherellina glandella Whitfield, 2.
Leperditia carbonaria Hall, 8.
Phillipsia ? (pygidium.) 1.
Deltodopsis stludovici St. J. and W., 1.

The Springvale beds and the Pella beds were evidently deposited some distance off shore in comparatively deep and quiet waters. Individual beds persist for considerable distances, especially in the latter. The presence of rhizopod shells in these also points to the correctness of this view. With regard to the Verdi beds, it has been supposed that the presence of sand, often cross-bedded, and the brecciated character, especially prominent in the Upper Verdi, should indicate littoral conditions of deposition. Against this view is the general absence of plant remains and the frequent presence of crinoid stems. The writer would remind readers interested in this question, that sand quite as coarse as that in the Verdi beds is found associated with crinoid stems in deposits now forming on the outer slope of the continental shelf in the Atlantic ocean, at depths exceeding 3,000 feet. This sand is always well worn and is apparently moved by bottom currents. It seems that such currents may very well produce cross-bedded deposits. And why not also cause brecciation in yet plastic rocks by local erosion and settling? The persistence of one thin seam of marl over many miles of territory testifies at any rate to off shore conditions during the latter part of the Verdi stage.

But little need be said on the subject of the correlation of these deposits with the Lower Carboniferous divisions elsewhere. The clays of the Springvale beds resemble those of the Keokuk in having geode-like concretions, but they differ from them most markedly in their lack of fossils and in their dolomitic character. Possibly their dolomitization was the cause of the destruction of their fossil remains, and they may be an attenuated equivalent of the Keokuk formation. There is no decisive evidence on this

point. Here, as in Washington county,* there are no sharp limits to be drawn between any of the members of the Saint Louis as above described. They all merge into each other by slow gradations in composition, bedding and structure.

THE DES MOINES.

By far the greater part of the area of the county is covered by the base of the Coal Measures, usually known as the Des Moines. These beds overlie the eroded and uneven surface of the Saint Louis formation everywhere, except some tracts of uncertain extent along the north boundary of the county and some comparatively narrow strips of land in the valleys of the principal streams where the underlying Saint Louis has been laid bare and appears as already described. The Des Moines consists of shales and sandstone with seams of limestone and coal and range from a few to at least 150 feet in thickness.

Walnut Township.—Over the northeast part of this township the Des Moines has been mostly removed by erosion, for it is only rarely seen. In sections 1 and 2 the valley which is followed by the Iowa Central railroad exposes small outliers of the Des Moines, mostly sandstone. Other instances of small outliers were noted in Burr Oak creek, near the center of the west line of section 15; in a ravine near the southwest corner of section 11; in a creek in the southwest quarter of the southwest quarter of section 12 (where it consists of yellow sandstone with imprints of lepidodendron and with imbedded pieces of charcoal); in the road following the east line of the southeast quarter of section 14; to the east of Walnut creek, in the northeast quarter of the northwest quarter of section 28 (here consisting of shales); in the north bank of Rocky Branch near the southwest corner of section 34 (also shale). Aside from these occurrences dark shale, no doubt belonging to the Coal Measures, have been encountered in some wells on the uplands, as in the northeast quarter of section 34, and in the south half of section 14. As most of these observations are on the lowlands, where erosion has been most extensive, there is no doubt that the Des Moines underlies the drift on considerable tracts of the uplands, especially to the southwest.

* Bain; Iowa Geol Surv., Vol. V, p. 149.

Lockridge Township.—Here most of the uplands are evidently overlain by the Coal Measures. In sections 4, 5 and 6 small exposures are occasionally seen in the bed and the banks of Rocky Branch, and these usually consist of sandstone. In the southwest quarter of the southwest quarter of section 14 coal was for some time mined in a seam almost in immediate contact with the underlying Saint Louis marls. On Brush creek Coal Measure shales are frequently and extensively exposed, and coal mines have been successfully operated for a long time. Near the north quarter post of section 29 shales and shaly sandstone of this age rise to an elevation of thirty feet above the bed of the stream in its south bank, and near the bridge in the wagon road close by these are interbedded with a seam of coal about fourteen inches in thickness. In section 27 there have been some of the productive mines in the county, and shales, shaly sandstone and thin seams of coal are frequently exposed in the south bank of the creek. Again, in section 36, in a run crossing the northwest corner of the section, coal has also been mined and there is exposed a ledge of yellowish gray, hard sandstone some twelve feet in thickness and containing imprints of leaves and stems of Stigmaria. Several of the upland wells have entered black shales and sandstones, evidently belonging to the Coal Measures.

The nature of the formation in this township is well shown in some of the explorations that have been made in connection with the mining of coal. The shaft of the mine just mentioned was only 25 feet deep. Under the surface dirt there was first some sandstone and then dark shale, under which lay the coal seam, in all 42 inches in thickness. This consisted of eight inches of a tough cannel coal above, thirteen inches of ordinary bituminous coal, then three inches of fire clay, and below this eighteen inches of bituminous coal. The bank was worked for a couple of seasons and then abandoned on account of water. In section 27 coal has been mined for the last forty years, and most of the coal has been removed from the entire northeast quarter of the southwest quarter of the section. The seam lies at an elevation slightly below the level of Brush creek. It has been found to be occasionally traversed by horsebacks of shaly material, locally known as "rolls," but these have not been of such frequency as to serious-

ly affect the mining operations. Some faults have also been encountered. The McGregor shaft, which was located on the northwest corner of the northwest quarter of the southwest quarter of this section, and on the bottom of a south tributary of brush creek, was only a little more than fifty feet deep, going through the following section:

I. SECTION OF THE McGREGOR COAL SHAFT.

		FEET.
12.	Surface material (drift)	10
.12.	Surface material (drift)	10
11.	Clay shale	3
10.	Blue shale	8
9.	Coal	2
8.	Fire clay	2
7.	Shale and black miner's slate, which was quite bituminous and had a brown streak	25
6.	Coal	3½
5.	Seam of pyrites	¼
4.	Coal	1
3.	Fire clay	3
2.	Green shale	8
1.	Hard black rock with some shells (probably Saint Louis limestone)	1

Most of the coal in this seam in the forty acre tract east of this has been mined by W. Brown & Co. Some acres are left near the center of the section (27) and a mine is now operated on this tract by W. C. Smith Coal Company, marketing the output in Mt. Pleasant, New London, Fairfield and to the country trade. The top of this shaft is sixty feet above the bed of Brush creek and it is ninety feet deep, going through the following section:

II. SECTION OF W. G SMITH COAL COMPANY'S SHAFT.

		FEET.
6.	Drift	54
5.	Shale	1
4.	Yellow fire clay	3
3.	Black shale	9
2.	Black miner's slate, containing in the basal part which forms the roof in the mine, imprints of *Sigillaria leptoderma* Lesq., *Lepidodendron distans* Lesq., *L. aculeatum* Sternb, *Lepidophyllum* ? (loose and separate, brown and somewhat flattened spores, scattered through the shale), and *Lingula mytiloides* Cox	20
1.	Coal	4½

The shaft was made last season and the entries were only extended a few rods, when the mine was visited by the writer. Operations are somewhat impeded by water, which is raised by horse power. As far as explored, the coal dips one foot in ten to the north and on the south of the shaft there is a fault with a downthrow of five feet in the same direction. The fault plane itself has a dip to the north of about 32° and trends W. 15° S.

Round Prairie Township.—In the north two-thirds of this township the drift is heavy and the bed rock is not often exposed. Most likely the Coal Measures underlie the drift over most of the territory. Some coal has been mined on the Wolf creek bottom in the northwest quarter of the southwest quarter of section 3. It was near the surface. In the tributaries of the Cedar, and on the Cedar itself, there are several places where the Coal Measures come into view. In a ravine running south in the southeast quarter of section 35, and at a distance of about a quarter of a mile from the main creek, a sandstone, four feet thick, rests unconformably on the Saint Louis limestone. It is quite coarse, grayish white, and contained imbedded fragments of chert and fossils of the Saint Louis and was impregnated with marcasite. Farther down the same ravine there were black shales in the bank of the run. At this place some coal has been taken out by drifting in the opposite bank, and the following section is seen.

III.

		FEET.
5.	Black shale	12
4.	White sandstone with imbedded small fragments of charcoal	1½
3.	Fine-grained, soft, arenaceous material	1
2.	White arenaceous shale	3
1.	White sandstone	3

To the west, along Cedar creek, sandstone of this division appears in several places overlying the Saint Louis uncomformably, coming down sometimes almost to the bed of the stream and sometimes resting on the limestone fifty feet up in the bluff.

Penn Township.—In the north part of this township no exposures of the Coal Measures have been observed and in all probability the Saint Louis directly underlies the drift in most of this territory. In the south half the most productive coal

mines in the county have been located and the formation is apparently quite continuous, though natural exposures are infrequent. Some of these are seen in the banks of South Walnut creek in the northwest quarter of section 26, and in sections 27 and 23, and consist of sandstone, greenish gray shales, black shales and concretionary, discontinuous ledges of black shaly limestone, with thin seams of coal. One-fourth of a mile northwest of the center of section 32 a layer of hard sandstone containing fragments of charcoal was seen to rest on three feet of black fissile shale in the south bank of the south fork of Walnut creek. Most of the old coal banks have been located in sections 26, 27, 32, 33 and 34, and the local character of the formation is best revealed in the explorations made in connection with these enterprises. The seam which has been mined lies about on the level of the bed of the creek. In the west half of section 26 some coal has been taken out by drifting into the base of the south bluff almost in sight of an outcrop of the Saint Louis limestone in the bed of the creek. The only mines now worked in the vicinity of Perlee are in section 27. One of these was opened this last season (1901) by Green and Looney and is located in a run on the south bluff of the south branch of Walnut creek, south of the center of the section. It is only some twenty feet deep. The coal is from three to four feet thick and is overlain by about ten feet of dark shale in which there are three layers of calcareous material. One of these lies two feet above the coal and is fine-grained and compact and traversed by many small vertical fissures, which have been filled with calcite and zinc blende. The two other layers are discontinuous and apparently more concretionary, lying respectively two and five feet above the first one. In the lower part of the dark shale a small Orthoceras, a small Chonetes, and fragments of fish teeth were noted. North of the creek in this section several coal banks have also been in operation, one of which lies close to the old bed of the C., R. I. & P. railroad. The old Washington County Coal Company worked several mines in sections 32 and 33 on the south side of the south branch of Walnut creek. A section of one of the shafts used by this company is given by Keyes as follows:*

* Iowa Geol. Surv., Vol. II, p. 395.

IV. SECTION OF A SHAFT OF THE WASHINGTON COUNTY COAL COMPANY. PERLEE.

		FEET.
29.	Drift	33
28.	Sand	3
27.	Clay, dark, shaly	20
26.	Shale, black	6
25.	Coal	3½
24.	Fire clay and shale	10
23.	Coal, shaly	3½
22.	Fire clay	2

The downward continuation of this section as seen in a prospecting hole, beginning under the coal worked, is given by the same author as follows:

		FEET.
21.	Mixed clays	18
20.	Gray shale	10
19.	Sandstone	12
18.	Limestone, gray, impure	8
17.	Sandstone, fine-grained, with brown, flinty partings, laminated, yellowish color	22
16.	Sandstone, bluish, fine-grained, heavily bedded.	20
15.	Sand shale	10
14.	Lime rock, impure	2
13.	Sand shale, gray, fine-grained	8
12.	Clay shale, blue	3
11.	Sand shale, blue, with thin, irregularly bedded, impure sand rock	37
10.	Limestone, impure, buff colored, fragmentary	2
9.	Clays, marly, blue, with small fossils	1
8.	Limestone, impure, bluish	3
7.	Sand shale, light blue, with sandstone partings	7
6.	Limestone, compact, gray, fragmentary	2
5.	Shale, argillaceous, blue and limestone	2½
4.	Shale, argillaceous, gray	3½
3.	Limestone, concretionary, compact, light gray.	4
2.	Marl, gray	2½
1.	Limestone, concretionary, light, with gray clay partings	22

Mr. Keyes refers the lowest ten numbers in the above section to the Saint Louis. Judging from the descriptions alone, the present writer would include in this the lowest nineteen numbers. On some of the shale dumps near the old mines in the southwest quarter of the northwest quarter of section 33 there were observed some lumps of what appears to be a mineralized

charcoal, in which silica fills the pores of the vegetable cell work. Some lumps were six inches in longest diameter. Part of the woody tissue bears the marks of tracheids. There were also some concretions of clay ironstone and large broken lumps of a perfectly black sandstone, consisting of crystalline quartz grains imbedded in a carbonaceous matrix. Old miners say that cakes of this material were sometimes found on the upper surface of the coal seam. All of these shafts were quite shallow, ranging from forty to one hundred feet in depth.

A partial record of the shaft of the Jefferson mine near the station at Perlee is given by Keyes, as follows:*

V. PARTIAL SECTION OF THE JEFFERSON COUNTY COAL COMPANY'S SHAFT NEAR PERLEE.

		FEET.
5.	Shale, gray anu clayey above, becoming black, fissile below	15
4.	Coal	3
3.	Fire clay, changing downward into gray clay shales	14
2.	Shale, highly bituminous and coaly in places	3
1.	Fire clay, exposed	1

On the old dump of this mine there were found some large pieces of silicified trunks of trees, which must have been two feet in diameter. In some of the fragments tracheids could be observed on the woody cells with a weak hand lens. There were also some fissile, gray, calcareous concretions varying from four to twenty inches in diameter and these were quite rich in fossils, such as *Nautilus*, sp. (small), *Orbiculoidea missouriensis* Shum., *Orthoceras rushensis* McChesney (?) *Pleurotomaria illinoisensis* W., *Productus muricatus* N. & P., *P. nanus* M. & W., *Pugnax rockymontana* Marcou, *P. uta* Marcou, *Schizodus alpina* Hall (?), *Straparollus pernodosus* M. & W. On another old shale dump of a mine on the northeast quarter of the northeast quarter of this section some more silicified wood was noted and also some fossil-bearing concretions of a similar structure containing *Clinopista radiata* Hall (?), *Orthoceras rushensis* McChesney (?), *Orbiculoidea missouriensis* Schumard, *Pleurotomaria illinoisensis* W., *Pleurotomaria*, sp. undet., *Productus muricatus* N. & P., and *Pugnax uta* Marcou.

* Iowa Geol. Surv., Vol. II, p. 397.

The Jefferson County Coal Company once made a drill hole on the upland slope about one-third of a mile east of the center of this section, and an old miner gives the following section of this exploration from memory:

VI. SECTION OF THE JEFFERSON COUNTY COAL COMPANY'S DRILL HOLE.

		FEET
3.	Drift	30
2.	Shales, fire clay, and some seams of coal	70
1.	"Soapstone" and limestone (evidently belonging to the Saint Louis)	100

From this and the previous sections it is evident that the depth of the Coal Measures in this locality is quite limited, not much exceeding one hundred feet. The underlying Saint Louis is exposed in the creeks both to the north and to the east. A large block of limestone was observed in the bed of the creek less than three-fourths of a mile west of Perlee. While it was in such a place that it could not be with certainty said to belong to an undisturbed ledge, it evidently had not been far removed from this. The principal seam, which has been worked, is near the base of the formation and has in places been found to run out against the drift, showing that preglacial erosion extended below the level of the coal in some places. The area on which mines have been worked follows the south branch of Walnut creek a distance of about three miles, being a mile wide. The total area of the land worked is less than one square mile and most of this has not been far from the creek.

Buchanan Township.—The Coal Measures underlie the drift over the greater part of this township, but they rarely come into view owing to the comparatively small depth of the drainage valleys. Excepting some unimportant exposures in Rocky Branch the principal sections are seen on Brush creek. Coal was for some time mined by drifting into the base of the south bluff of this creek, near the northeast corner of the northwest quarter of the southwest quarter of section 10. This is only two miles south and one mile east of Perlee and the coal here is the same as at the latter place. On the old shale banks lumps of the same black sandstone were seen, here with impressions of the bark of trees, and associated with small indurated aggregations of charcoal. There are also the same calcareous concretions con-

taining some of the same fossils as those near Perlee. A quarter of a mile south and a little east of the center of the section, the south bank of the creek exposes two feet of the Saint Louis limestone and underlying this there is:

VII.

		FEET.
4.	Gray shale	1½
3.	Carbonaceous black and fissile shale	2
2.	Fire clay	2
1.	Yellow and irregularly bedded sandstone with imprints of stems and leaves of Stigmaria	1 to 3

In the south bank of the creek, in the northwest quarter of the northwest quarter of section 14, a dark shale is seen which contains some clay ironstone concretions of large size, from two to three feet in diameter. In one of these the upper side consisted of a layer of cone-in-cone while the body was made up of a mass of small spherical concretions of the size of large shot and of a radiate structure. Imbedded in this mass lay some kidney-shaped concretions of black calcareous material containing fragments of brachiopods. Near the center of section 13 the north bank of the creek exposes eight feet of a dark laminated shale in which there are several bands of clay ironstone, some containing a Seminula and *Lingula mytiloides*. Not far from this, on the south bank of the creek, a pile of shale and an abandoned pit indicate the site of an old coal bank. In sections 27 and 35 some explorations by deep wells show that the Coal Measures are absent and that the drift rests on the Saint Louis limestone.

Cedar Township.—Most of this township is no doubt underlain by the Coal Measures, although they have been subjected to quite extensive erosion. On Crow creek, in the central sections the drift extends below the bed of the stream as far down as to the southwest of the center of section 27, below the wagon bridge, where the creek cuts into three or four feet of dark shale in the left bank. This shale contains considerable pyrites and also numerous crystals of selenite, some of which measured four inches in length.

Going up Cedar creek fifteen feet of dark shale is seen in the south bank at the south end of the loop which it makes to the south in the east part of section 35. A band of kidney-shaped

concretions lie at a level a few feet above the base of this bank. In the bed of the creek and under the shale there is a dark, and in places black, coarse sandstone, which is charged with minute grains of pyrites, that apparently had been deposited by infiltration. Some of the sandstone has a calcareous cement of similar origin, and also contains fragments of the Saint Louis limestone. This is no doubt the basal ledge of the Coal Measures resting directly on the Saint Louis limestone. A little south of the center of the northeast quarter of section 35 the east bank of the creek consists of Coal Measure shales and sandstone for a distance of twenty rods. The section is as follows:

VIII. SECTION IN THE LEFT BANK OF CEDAR CREEK NEAR THE CENTER OF THE NE. ¼ OF SEC. 35 CEDAR TOWNSHIP.

		FEET.
5.	Black shale, slightly calcareous and fossil-bearing at the base	8
4.	A layer of calcareous clay ironstone concretions. These concretions vary in size from two inches to nearly two feet in longest diameter. The smaller ones were found to have a core of calcite and zinc blende, while most of the larger ones were checked internally by numerous shrinkage cracks running vertically and filled by the same minerals	½
3.	Black shale, laminated and fissile below, and containing in the uppermost ten inches several fossils such as *Productus semireticulatus* Martin., *P. longispinus* Sow., *P. nanus* M. & W., *P. cora* D'Orbigny, *Spirifer cameracus* Morton, *Chonetes*, sp., *Seminula argentea*, and quite an abundance of a simple cyathopylloid coral measuring about one and a half inches in length. In the lower part there are numerous concretionary cakes of iron pyrites measuring some two inches in diameter with a thickness of about a half an inch	8
2.	Fire clay	4
1.	Sandstone, which at the point farthest south encroaches upon and replaces the fire clay. At the southernmost end a six inch seam of coal separates this sandstone from the dark shale (No. 3) above the fire clay farther north	4

taining some of the same fossils as those near Perlee. A quarter of a mile south and a little east of the center of the section, the south bank of the creek exposes two feet of the Saint Louis limestone and underlying this there is:

VII.

		Feet.
4.	Gray shale	1½
3.	Carbonaceous black and fissile shale	2
2.	Fire clay	2
1.	Yellow and irregularly bedded sandstone with imprints of stems and leaves of Stigmaria	1 to 3

In the south bank of the creek, in the northwest quarter of the northwest quarter of section 14, a dark shale is seen which contains some clay ironstone concretions of large size, from two to three feet in diameter. In one of these the upper side consisted of a layer of cone-in-cone while the body was made up of a mass of small spherical concretions of the size of large shot and of a radiate structure. Imbedded in this mass lay some kidney-shaped concretions of black calcareous material containing fragments of brachiopods. Near the center of section 13 the north bank of the creek exposes eight feet of a dark laminated shale in which there are several bands of clay ironstone, some containing a Seminula and *Lingula mytiloides*. Not far from this, on the south bank of the creek, a pile of shale and an abandoned pit indicate the site of an old coal bank. In sections 27 and 35 some explorations by deep wells show that the Coal Measures are absent and that the drift rests on the Saint Louis limestone.

Cedar Township.—Most of this township is no doubt underlain by the Coal Measures, although they have been subjected to quite extensive erosion. On Crow creek, in the central sections the drift extends below the bed of the stream as far down as to the southwest of the center of section 27, below the wagon bridge where the creek cuts into three or four feet of dark shale in the left bank. This shale contains considerable pyrites and al numerous crystals of selenite, some of which measured fo inches in length.

Going up Cedar creek fifteen feet of dark shale is seen in t south bank at the south end of the loop which it makes to south in the east part of section 35. A band of kidney-sha

concretions lie at a level a few feet above the base of the bank. In the bed of the creek and under the same there is a dark, and in places black, coarse sandstone [illegible] charged with minute [illegible]

taining some of the same fossils as those near Perlee. A quarter of a mile south and a little east of the center of the section, the south bank of the creek exposes two feet of the Saint Louis limestone and underlying this there is:

VII.

		Feet.
4.	Gray shale	$1\frac{1}{2}$
3.	Carbonaceous black and fissile shale	2
2.	Fire clay	2
1.	Yellow and irregularly bedded sandstone with imprints of stems and leaves of Stigmaria	1 to 3

In the south bank of the creek, in the northwest quarter of the northwest quarter of section 14, a dark shale is seen which contains some clay ironstone concretions of large size, from two to three feet in diameter. In one of these the upper side consisted of a layer of cone-in-cone while the body was made up of a mass of small spherical concretions of the size of large shot and of a radiate structure. Imbedded in this mass lay some kidney-shaped concretions of black calcareous material containing fragments of brachiopods. Near the center of section 13 the north bank of the creek exposes eight feet of a dark laminated shale in which there are several bands of clay ironstone, some containing a Seminula and *Lingula mytiloides*. Not far from this, on the south bank of the creek, a pile of shale and an abandoned pit indicate the site of an old coal bank. In sections 27 and 35 some explorations by deep wells show that the Coal Measures are absent and that the drift rests on the Saint Louis limestone.

Cedar Township.—Most of this township is no doubt underlain by the Coal Measures, although they have been subjected to quite extensive erosion. On Crow creek, in the central sections the drift extends below the bed of the stream as far down as to the southwest of the center of section 27, below the wagon bridge, where the creek cuts into three or four feet of dark shale in the left bank. This shale contains considerable pyrites and also numerous crystals of selenite, some of which measured four inches in length.

Going up Cedar creek fifteen feet of dark shale is seen in the south bank at the south end of the loop which it makes to the south in the east part of section 35. A band of kidney-shaped

concretions lie at a level a few feet above the base of this bank. In the bed of the creek and under the shale there is a dark, and in places black, coarse sandstone, which is charged with minute grains of pyrites, that apparently had been deposited by infiltration. Some of the sandstone has a calcareous cement of similar origin, and also contains fragments of the Saint Louis limestone. This is no doubt the basal ledge of the Coal Measures resting directly on the Saint Louis limestone. A little south of the center of the northeast quarter of section 35 the east bank of the creek consists of Coal Measure shales and sandstone for a distance of twenty rods. The section is as follows:

VIII. SECTION IN THE LEFT BANK OF CEDAR CREEK NEAR THE CENTER OF THE NE. ¼ OF SEC. 35 CEDAR TOWNSHIP.

	FEET.
5. Black shale, slightly calcareous and fossil-bearing at the base	8
4. A layer of calcareous clay ironstone concretions. These concretions vary in size from two inches to nearly two feet in longest diameter. The smaller ones were found to have a core of calcite and zinc blende, while most of the larger ones were checked internally by numerous shrinkage cracks running vertically and filled by the same minerals	½
3. Black shale, laminated and fissile below, and containing in the uppermost ten inches several fossils such as *Productus semireticulatus* Martin., *P. longispinus* Sow., *P. nanus* M. & W., *P. cora* D'Orbigny, *Spirifer cameracus* Morton, *Chonetes*, sp., *Seminula argentea*, and quite an abundance of a simple cyathopylloid coral measuring about one and a half inches in length. In the lower part there are numerous concretionary cakes of iron pyrites measuring some two inches in diameter with a thickness of about a half an inch	8
2. Fire clay	4
1. Sandstone, which at the point farthest south encroaches upon and replaces the fire clay. At the southernmost end a six inch seam of coal separates this sandstone from the dark shale (No. 3) above the fire clay farther north	4

These beds exhibit a gentle syncline, rising rather abruptly at the south end as much as ten feet. This attitude is probably not due to any flexure, but rather a feature of the original deposition, caused by the uneven surface of the underlying Saint Louis. A mile farther west pockets of Coal Measure shales and sandstone are occasionally seen at varying levels on the eroded surface of the lower formation. A dark shale like numbers 3, 4 and 5 in the above section, and with the same kind of concretions, appears in a ravine on the county line near the southwest corner of section 35.

For most of the distance that the creek runs in section 33 its south bank is a continuous exposure of Coal Measures in places resting upon a low ledge of Saint Louis limestone. Thus, near the east line of the section there is seen:

IX. SECTION IN THE BASAL PART OF THE COAL MEASURES IN THE SOUTH BANK OF CEDAR CREEK NEAR THE EAST LINE OF SEC. 33.

	FEET.
5. Dark shale, weathering to gray with some crystals of selenite	12
4. Black, bituminous shale containing an abundance of crystals of selenite and occasional cakes of fibrous gypsum. Some crystals and cakes measured five inches in length	1
3. Hard, gray or grayish-brown sandstone, occasionally black or greenish black from infiltration of pyrites and other materials. Impressions of stems of Stigmaria were noted on the upper surface of the ledge	2
Unconformity.	
2. Greenish shale with some thin and uniformly developed laminæ of fine arenaceous material (not well exposed)	4
Unconformity.	
1. Brecciated limestone of the Saint Louis stage, with some brecciated siliceous lumps	7

The Coal Measures also appear near the center of the east line of section 32 and in the south bank of Cedar creek in the southeast quarter of section 29, where they may be described as follows:

X. SECTION IN THE SOUTH BANK OF THE CEDAR IN THE SE. ¼ OF SEC. 29.

		FEET.
4.	Black shale	10
	green, stony, arenaceous rock	1½
	green stony, arenaceous rock	1½
2.	Green shale	4
	Unconformity.	
1.	Brecciated limestone of the Saint Louis group.	3

Numbers 2 and 3 in the above are identical with number 2 in the previous section, where they occur under a coarse sandstone. They appear again a little farther to the west, where the bluff shows the following succession of beds:

XI.

		FEET.
6.	Yellow sandstone	3
5.	Yellow shale	3
4.	Coal of the common bituminous kind above, changing into cannel coal below	1½
3.	Fire clay	3
2.	Black shale, becoming highly carbonaceous and bituminous below	6
1.	Green shale extending down to the bed of the creek	4

Above this place the valley of the creek is very wide and the bed rock is not so frequently seen. In section 19 coal has been mined in some shallow shafts, which are now abandoned. The strong mineral taste of the water in several wells indicate that the Coal Measures constitute the bed rock in most of this region.

Black Hawk Township.—In this territory the drainage valleys are shallow and the bed rock was not seen anywhere. That the Coal Measures underlie at least a part of this area is evident from the records of two wells. One of these is in section 6. (See well No. 1 in the table of well records.) It is situated on upland and the first 130 feet went through drift. Below this there were thirty feet of red and black shale. The other well is in the southwest quarter of section 27, and situated on an upland slope. Here there was eighty-five feet of drift and then shale with sandstone at the bottom. In the north the drift no doubt in some places rests on the Saint Louis, but it is probable that more than half of the area is covered by the later formation.

Fairfield Township.—(Excluding the tract in Tp. 71 N., R. X W.) In the three north tiers of sections the valleys are comparatively shallow and field observations on the bed rock were confined to the three south tiers. The Coal Measures underlie the greater part, if not all, of the township. All the deep wells from which records were secured entered either sandstone or shale under the drift. In the north half the thickness may average less than seventy-five feet, but in the south half it evidently averages more than one hundred feet, possibly in places reaching a depth of 150 feet. In the later region some of the wells have gone through several veins of coal, which disappear in short distances and vary considerably in thickness and elevation.

The greatest exposed depth of the formation is seen in the north bank of the Cedar near the center of the northwest quarter

FIG. 61. Exposure of Coal Measure strata in the north bank of Cedar creek, section 32, Fairfield township.

of section 32, where the creek is sapping a nearly vertical embankment almost forty feet high, (Fig. 61), which may be described as below:

XII. SECTION OF THE COAL MEASURES IN THE NORTH BANK OF CEDAR CREEK NEAR THE CENTER OF THE NW. ¼ OF SEC. 32.

		Feet
7.	Soft arenaceous shale with alterating bands of sandstone	7
6.	Gray, cross-bedded and somewhat coarse sandstone	10
5.	A wedge of gray arenaceous shale, thinning towards the west	3
4.	Gray sandstone, slightly cross-bedded and micaceous	7
3.	Coal, thinning to the east and running out to the west, greatest thickness	1½
2.	Fire clay, gray and arenaceous	3
1.	Fire clay and shale (partly concealed)	7

One-fourth of a mile south of the center of section 28 and on the west side of the wagon road where this crosses the old railroad embankment is located the clay bank of the Rainy Bros.' tile factory. The clay which is hauled away from this pit consists of a disintegrated Coal Measure shale, which is obtained by stripping, as it is covered by about fifteen feet of loess and other drift. The bank is at present twenty-four feet high and the material seen is

XIII.

		Feet.
7.	Loess and bowlder clay	15
6.	Coal	½
5.	White fire clay	2
4.	Black shale with some small crystals of gypsum	3
3.	Coal	1
2.	White fire clay	4
1.	Greenish, fine-grained, micaceous sandstone	1

To the north along the creek in this section similar exposures are frequent and coal has been mined here since the early days of the settlement of this county. Several old shale dumps are seen along a ravine which follows the south side of the old railroad in the southwest quarter of the northwest quarter of section 27 and also in the northwest quarter of section 28. The principal coal seam occurs at depths varying from thirty to ten feet below the bottom of the streams and is from three to three and a half feet in thickness. Over it there is a black shale, which contains large septaria occasionally found to contain fossils such

mines in the county have been located and the formation is apparently quite continuous, though natural exposures are infrequent. Some of these are seen in the banks of South Walnut creek in the northwest quarter of section 26, and in sections 27 and 23, and consist of sandstone, greenish gray shales, black shales and concretionary, discontinuous ledges of black shaly limestone, with thin seams of coal. One-fourth of a mile northwest of the center of section 32 a layer of hard sandstone containing fragments of charcoal was seen to rest on three feet of black fissile shale in the south bank of the south fork of Walnut creek. Most of the old coal banks have been located in sections 26, 27, 32, 33 and 34, and the local character of the formation is best revealed in the explorations made in connection with these enterprises. The seam which has been mined lies about on the level of the bed of the creek. In the west half of section 26 some coal has been taken out by drifting into the base of the south bluff almost in sight of an outcrop of the Saint Louis limestone in the bed of the creek. The only mines now worked in the vicinity of Perlee are in section 27. One of these was opened this last season (1901) by Green and Looney and is located in a run on the south bluff of the south branch of Walnut creek, south of the center of the section. It is only some twenty feet deep. The coal is from three to four feet thick and is overlain by about ten feet of dark shale in which there are three layers of calcareous material. One of these lies two feet above the coal and is fine-grained and compact and traversed by many small vertical fissures, which have been filled with calcite and zinc blende. The two other layers are discontinuous and apparently more concretionary, lying respectively two and five feet above the first one. In the lower part of the dark shale a small Orthoceras, a small Chonetes, and fragments of fish teeth were noted. North of the creek in this section several coal banks have also been in operation, one of which lies close to the old bed of the C., R. I. & P. railroad. The old Washington County Coal Company worked several mines in sections 32 and 33 on the south side of the south branch of Walnut creek. A section of one of the shafts used by this company is given by Keyes as follows:*

* Iowa Geol. Surv., Vol. II, p. 395.

IV. SECTION OF A SHAFT OF THE WASHINGTON COUNTY COAL COMPANY. PERLEE.

		Feet.
29.	Drift	33
28.	Sand	3
27.	Clay, dark, shaly	20
26.	Shale, black	6
25.	Coal	3½
24.	Fire clay and shale	10
23.	Coal, shaly	3½
22.	Fire clay	2

The downward continuation of this section as seen in a prospecting hole, beginning under the coal worked, is given by the same author as follows:

		Feet.
21.	Mixed clays	18
20.	Gray shale	10
19.	Sandstone	12
18.	Limestone, gray, impure	8
17.	Sandstone, fine-grained, with brown, flinty partings, laminated, yellowish color	22
16.	Sandstone, bluish, fine-grained, heavily bedded	20
15.	Sand shale	10
14.	Lime rock, impure	2
13.	Sand shale, gray, fine-grained	8
12.	Clay shale, blue	3
11.	Sand shale, blue, with thin, irregularly bedded, impure sand rock	37
10.	Limestone, impure, buff colored, fragmentary	2
9.	Clays, marly, blue, with small fossils	1
8.	Limestone, impure, bluish	3
7.	Sand shale, light blue, with sandstone partings	7
6.	Limestone, compact, gray, fragmentary	2
5.	Shale, argillaceous, blue and limestone	2½
4.	Shale, argillaceous, gray	3½
3.	Limestone, concretionary, compact, light gray	4
2.	Marl, gray	2½
1.	Limestone, concretionary, light, with gray clay partings	22

Mr. Keyes refers the lowest ten numbers in the above section to the Saint Louis. Judging from the descriptions alone, the present writer would include in this the lowest nineteen numbers. On some of the shale dumps near the old mines in the southwest quarter of the northwest quarter of section 33 there were observed some lumps of what appears to be a mineralized

mines in the county have been located and the formation is apparently quite continuous, though natural exposures are infrequent. Some of these are seen in the banks of South Walnut creek in the northwest quarter of section 26, and in sections 27 and 23, and consist of sandstone, greenish gray shales, black shales and concretionary, discontinuous ledges of black shaly limestone, with thin seams of coal. One-fourth of a mile northwest of the center of section 32 a layer of hard sandstone containing fragments of charcoal was seen to rest on three feet of black fissile shale in the south bank of the south fork of Walnut creek. Most of the old coal banks have been located in sections 26, 27, 32, 33 and 34, and the local character of the formation is best revealed in the explorations made in connection with these enterprises. The seam which has been mined lies about on the level of the bed of the creek. In the west half of section 26 some coal has been taken out by drifting into the base of the south bluff almost in sight of an outcrop of the Saint Louis limestone in the bed of the creek. The only mines now worked in the vicinity of Perlee are in section 27. One of these was opened this last season (1901) by Green and Looney and is located in a run on the south bluff of the south branch of Walnut creek, south of the center of the section. It is only some twenty feet deep. The coal is from three to four feet thick and is overlain by about ten feet of dark shale in which there are three layers of calcareous material. One of these lies two feet above the coal and is fine-grained and compact and traversed by many small vertical fissures, which have been filled with calcite and zinc blende. The two other layers are discontinuous and apparently more concretionary, lying respectively two and five feet above the first one. In the lower part of the dark shale a small Orthoceras, a small Chonetes, and fragments of fish teeth were noted. North of the creek in this section several coal banks have also been in operation, one of which lies close to the old bed of the C., R. I. & P. railroad. The old Washington County Coal Company worked several mines in sections 32 and 33 on the south side of the south branch of Walnut creek. A section of one of the shafts used by this company is given by Keyes as follows:*

* Iowa Geol. Surv., Vol. II, p. 395.

charcoal, in which silica fills the pores of the vegetable cell work. Some lumps were six inches in longest diameter. Part of the woody tissue bears the marks of tracheids. There were also some concretions of clay ironstone and large broken lumps of a perfectly black sandstone, consisting of crystalline quartz grains imbedded in a carbonaceous matrix. Old miners say that cakes of this material were sometimes found on the upper surface of the coal seam. All of these shafts were quite shallow, ranging from forty to one hundred feet in depth.

A partial record of the shaft of the Jefferson mine near the station at Perlee is given by Keyes, as follows:*

V. PARTIAL SECTION OF THE JEFFERSON COUNTY COAL COMPANY'S SHAFT NEAR PERLEE.

		FEET.
5.	Shale, gray and clayey above, becoming black, fissile below	15
4.	Coal	3
3.	Fire clay, changing downward into gray clay shales	14
2.	Shale, highly bituminous and coaly in places	3
1.	Fire clay, exposed	1

On the old dump of this mine there were found some large pieces of silicified trunks of trees, which must have been two feet in diameter. In some of the fragments tracheids could be observed on the woody cells with a weak hand lens. There were also some fissile, gray, calcareous concretions varying from four to twenty inches in diameter and these were quite rich in fossils, such as *Naulilus,* sp. (small), *Orbiculoidea missouriensis* Shum., *Orthoceras rushensis* McChesney (?) *Pleurotomaria illinoisensis* W., *Productus muricatus* N. & P., *P. nanus* M. & W., *Pugnax rockymontana* Marcou, *P. uta* Marcou, *Schizodus alpina* Hall (?), *Straparollus pernodosus* M. & W. On another old shale dump of a mine on the northeast quarter of the northeast quarter of this section some more silicfied wood was noted and also some fossil-bearing concretions of a similar structure containing *Clinopista radiata* Hall (?), *Orthoceras rushensis* McChesney (?), *Orbiculoidea missouriensis* Schumard, *Pleurotomaria illinoisensis* W., *Pleurotomaria,* sp. undet., *Productus muricatus* N. & P., and *Pugnax uta* Marcou.

* Iowa Geol. Surv., Vol. II, p. 397.

The Jefferson County Coal Company once made a drill hole on the upland slope about one-third of a mile east of the center of this section, and an old miner gives the following section of this exploration from memory:

VI. SECTION OF THE JEFFERSON COUNTY COAL COMPANY'S DRILL HOLE

		Feet
3.	Drift	30
2.	Shales, fire clay, and some seams of coal	70
1.	"Soapstone" and limestone (evidently belonging to the Saint Louis)	100

From this and the previous sections it is evident that the depth of the Coal Measures in this locality is quite limited, not much exceeding one hundred feet. The underlying Saint Louis is exposed in the creeks both to the north and to the east. A large block of limestone was observed in the bed of the creek less than three-fourths of a mile west of Perlee. While it was in such a place that it could not be with certainty said to belong to an undisturbed ledge, it evidently had not been far removed from this. The principal seam, which has been worked, is near the base of the formation and has in places been found to run out against the drift, showing that preglacial erosion extended below the level of the coal in some places. The area on which mines have been worked follows the south branch of Walnut creek a distance of about three miles, being a mile wide. The total area of the land worked is less than one square mile and most of this has not been far from the creek.

Buchanan Township.—The Coal Measures underlie the drift over the greater part of this township, but they rarely come into view owing to the comparatively small depth of the drainage valleys. Excepting some unimportant exposures in Rocky Branch the principal sections are seen on Brush creek. Coal was for some time mined by drifting into the base of the south bluff of this creek, near the northeast corner of the northwest quarter of the southwest quarter of section 10. This is only two miles south and one mile east of Perlee and the coal here is the same as at the latter place. On the old shale banks lumps of the same black sandstone were seen, here with impressions of the bark of trees, and associated with small indurated aggregations of charcoal. There are also the same calcareous concretions con-

taining some of the same fossils as those near Perlee. A quarter of a mile south and a little east of the center of the section, the south bank of the creek exposes two feet of the Saint Louis limestone and underlying this there is:

VII.

		FEET.
4.	Gray shale	$1\frac{1}{2}$
3.	Carbonaceous black and fissile shale	2
2.	Fire clay	2
1.	Yellow and irregularly bedded sandstone with imprints of stems and leaves of Stigmaria	1 to 3

In the south bank of the creek, in the northwest quarter of the northwest quarter of section 14, a dark shale is seen which contains some clay ironstone concretions of large size, from two to three feet in diameter. In one of these the upper side consisted of a layer of cone-in-cone while the body was made up of a mass of small spherical concretions of the size of large shot and of a radiate structure. Imbedded in this mass lay some kidney-shaped concretions of black calcareous material containing fragments of brachiopods. Near the center of section 13 the north bank of the creek exposes eight feet of a dark laminated shale in which there are several bands of clay ironstone, some containing a Seminula and *Lingula mytiloides*. Not far from this, on the south bank of the creek, a pile of shale and an abandoned pit indicate the site of an old coal bank. In sections 27 and 35 some explorations by deep wells show that the Coal Measures are absent and that the drift rests on the Saint Louis limestone.

Cedar Township.—Most of this township is no doubt underlain by the Coal Measures, although they have been subjected to quite extensive erosion. On Crow creek, in the central sections the drift extends below the bed of the stream as far down as to the southwest of the center of section 27, below the wagon bridge, where the creek cuts into three or four feet of dark shale in the left bank. This shale contains considerable pyrites and also numerous crystals of selenite, some of which measured four inches in length.

Going up Cedar creek fifteen feet of dark shale is seen in the south bank at the south end of the loop which it makes to the south in the east part of section 35. A band of kidney-shaped

concretions lie at a level a few feet above the base of this bank. In the bed of the creek and under the shale there is a dark, and in places black, coarse sandstone, which is charged with minute grains of pyrites, that apparently had been deposited by infiltration. Some of the sandstone has a calcareous cement of similar origin, and also contains fragments of the Saint Louis limestone. This is no doubt the basal ledge of the Coal Measures resting directly on the Saint Louis limestone. A little south of the center of the northeast quarter of section 35 the east bank of the creek consists of Coal Measure shales and sandstone for a distance of twenty rods. The section is as follows:

VIII. SECTION IN THE LEFT BANK OF CEDAR CREEK NEAR THE CENTER OF THE NE. ¼ OF SEC. 35 CEDAR TOWNSHIP.

		FEET.
5.	Black shale, slightly calcareous and fossil-bearing at the base	8
4.	A layer of calcareous clay ironstone concretions. These concretions vary in size from two inches to nearly two feet in longest diameter. The smaller ones were found to have a core of calcite and zinc blende, while most of the larger ones were checked internally by numerous shrinkage cracks running vertically and filled by the same minerals	½
3.	Black shale, laminated and fissile below, and containing in the uppermost ten inches several fossils such as *Productus semireticulatus* Martin., *P. longispinus* Sow., *P. nanus* M. & W., *P. cora* D'Orbigny, *Spirifer cameracus* Morton, *Chonetes*, sp., *Seminula argentea*, and quite an abundance of a simple cyathopylloid coral measuring about one and a half inches in length. In the lower part there are numerous concretionary cakes of iron pyrites measuring some two inches in diameter with a thickness of about a half an inch	8
2.	Fire clay	4
1.	Sandstone, which at the point farthest south encroaches upon and replaces the fire clay. At the southernmost end a six inch seam of coal separates this sandstone from the dark shale (No. 3) above the fire clay farther north	4

point. Here, as in Washington county,* there are no sharp limits to be drawn between any of the members of the Saint Louis as above described. They all merge into each other by slow gradations in composition, bedding and structure.

THE DES MOINES.

By far the greater part of the area of the county is covered by the base of the Coal Measures, usually known as the Des Moines. These beds overlie the eroded and uneven surface of the Saint Louis formation everywhere, except some tracts of uncertain extent along the north boundary of the county and some comparatively narrow strips of land in the valleys of the principal streams where the underlying Saint Louis has been laid bare and appears as already described. The Des Moines consists of shales and sandstone with seams of limestone and coal and range from a few to at least 150 feet in thickness.

Walnut Township.—Over the northeast part of this township the Des Moines has been mostly removed by erosion, for it is only rarely seen. In sections 1 and 2 the valley which is followed by the Iowa Central railroad exposes small outliers of the Des Moines, mostly sandstone. Other instances of small outliers were noted in Burr Oak creek, near the center of the west line of section 15; in a ravine near the southwest corner of section 11; in a creek in the southwest quarter of the southwest quarter of section 12 (where it consists of yellow sandstone with imprints of lepidodendron and with imbedded pieces of charcoal); in the road following the east line of the southeast quarter of section 14; to the east of Walnut creek, in the northeast quarter of the northwest quarter of section 28 (here consisting of shales); in the north bank of Rocky Branch near the southwest corner of section 34 (also shale). Aside from these occurrences dark shale, no doubt belonging to the Coal Measures, have been encountered in some wells on the uplands, as in the northeast quarter of section 34, and in the south half of section 14. As most of these observations are on the lowlands, where erosion has been most extensive, there is no doubt that the Des Moines underlies the drift on considerable tracts of the uplands, especially to the southwest.

* Bain; Iowa Geol Surv., Vol. V, p. 149.

Lockridge Township.—Here most of the uplands are evidently overlain by the Coal Measures. In sections 4, 5 and 6 small exposures are occasionally seen in the bed and the banks of Rocky Branch, and these usually consist of sandstone. In the southwest quarter of the southwest quarter of section 14 coal was for some time mined in a seam almost in immediate contact with the underlying Saint Louis marls. On Brush creek Coal Measure shales are frequently and extensively exposed, and coal mines have been successfully operated for a long time. Near the north quarter post of section 29 shales and shaly sandstone of this age rise to an elevation of thirty feet above the bed of the stream in its south bank, and near the bridge in the wagon road close by these are interbedded with a seam of coal about fourteen inches in thickness. In section 27 there have been some of the productive mines in the county, and shales, shaly sandstone and thin seams of coal are frequently exposed in the south bank of the creek. Again, in section 36, in a run crossing the northwest corner of the section, coal has also been mined and there is exposed a ledge of yellowish gray, hard sandstone some twelve feet in thickness and containing imprints of leaves and stems of Stigmaria. Several of the upland wells have entered black shales and sandstones, evidently belonging to the Coal Measures.

The nature of the formation in this township is well shown in some of the explorations that have been made in connection with the mining of coal. The shaft of the mine just mentioned was only 25 feet deep. Under the surface dirt there was first some sandstone and then dark shale, under which lay the coal seam, in all 42 inches in thickness. This consisted of eight inches of a tough cannel coal above, thirteen inches of ordinary bituminous coal, then three inches of fire clay, and below this eighteen inches of bituminous coal. The bank was worked for a couple of seasons and then abandoned on account of water. In section 27 coal has been mined for the last forty years, and most of the coal has been removed from the entire northeast quarter of the southwest quarter of the section. The seam lies at an elevation slightly below the level of Brush creek. It has been found to be occasionally traversed by horsebacks of shaly material, locally known as "rolls," but these have not been of such frequency as to serious-

ly affect the mining operations. Some faults have also been encountered. The McGregor shaft, which was located on the northwest corner of the northwest quarter of the southwest quarter of this section, and on the bottom of a south tributary of brush creek, was only a little more than fifty feet deep, going through the following section:

I. SECTION OF THE McGREGOR COAL SHAFT.

		FEET.
12.	Surface material (drift)	10
.12.	Surface material (drift)	10
11.	Clay shale	3
10.	Blue shale	8
9.	Coal	2
8.	Fire clay	2
7.	Shale and black miner's slate, which was quite bituminous and had a brown streak	25
6.	Coal	3½
5.	Seam of pyrites	¼
4.	Coal	1
3.	Fire clay	3
2.	Green shale	8
1.	Hard black rock with some shells (probably Saint Louis limestone)	1

Most of the coal in this seam in the forty acre tract east of this has been mined by W. Brown & Co. Some acres are left near the center of the section (27) and a mine is now operated on this tract by W. C. Smith Coal Company, marketing the output in Mt. Pleasant, New London, Fairfield and to the country trade. The top of this shaft is sixty feet above the bed of Brush creek and it is ninety feet deep, going through the following section:

II. SECTION OF W. G SMITH COAL COMPANY'S SHAFT.

		FEET.
6.	Drift	54
5.	Shale	1
4.	Yellow fire clay	3
3.	Black shale	9
2.	Black miner's slate, containing in the basal part which forms the roof in the mine, imprints of *Sigillaria leptoderma* Lesq., *Lepidodendron distans* Lesq., *L. aculeatum* Sternb, *Lepidophyllum* ? (loose and separate, brown and somewhat flattened spores, scattered through the shale), and *Lingula mytiloides* Cox	20
1.	Coal	4½

The shaft was made last season and the entries were only extended a few rods, when the mine was visited by the writer. Operations are somewhat impeded by water, which is raised by horse power. As far as explored, the coal dips one foot in ten to the north and on the south of the shaft there is a fault with a downthrow of five feet in the same direction. The fault plane itself has a dip to the north of about 32° and trends W. 15° S.

Round Prairie Township.—In the north two-thirds of this township the drift is heavy and the bed rock is not often exposed. Most likely the Coal Measures underlie the drift over most of the territory. Some coal has been mined on the Wolf creek bottom in the northwest quarter of the southwest quarter of section 3. It was near the surface. In the tributaries of the Cedar, and on the Cedar itself, there are several places where the Coal Measures come into view. In a ravine running south in the southeast quarter of section 35, and at a distance of about a quarter of a mile from the main creek, a sandstone, four feet thick, rests unconformably on the Saint Louis limestone. It is quite coarse, grayish white, and contained imbedded fragments of chert and fossils of the Saint Louis and was impregnated with marcasite. Farther down the same ravine there were black shales in the bank of the run. At this place some coal has been taken out by drifting in the opposite bank, and the following section is seen.

III.

		FEET.
5.	Black shale	12
4.	White sandstone with imbedded small fragments of charcoal	1½
3.	Fine-grained, soft, arenaceous material	1
2.	White arenaceous shale	3
1.	White sandstone	3

To the west, along Cedar creek, sandstone of this division appears in several places overlying the Saint Louis uncomformably, coming down sometimes almost to the bed of the stream and sometimes resting on the limestone fifty feet up in the bluff.

Penn Township.—In the north part of this township no exposures of the Coal Measures have been observed and in all probability the Saint Louis directly underlies the drift in most of this territory. In the south half the most productive coal

mines in the county have been located and the formation is apparently quite continuous, though natural exposures are infrequent. Some of these are seen in the banks of South Walnut creek in the northwest quarter of section 26, and in sections 27 and 23, and consist of sandstone, greenish gray shales, black shales and concretionary, discontinuous ledges of black shaly limestone, with thin seams of coal. One-fourth of a mile northwest of the center of section 32 a layer of hard sandstone containing fragments of charcoal was seen to rest on three feet of black fissile shale in the south bank of the south fork of Walnut creek. Most of the old coal banks have been located in sections 26, 27, 32, 33 and 34, and the local character of the formation is best revealed in the explorations made in connection with these enterprises. The seam which has been mined lies about on the level of the bed of the creek. In the west half of section 26 some coal has been taken out by drifting into the base of the south bluff almost in sight of an outcrop of the Saint Louis limestone in the bed of the creek. The only mines now worked in the vicinity of Perlee are in section 27. One of these was opened this last season (1901) by Green and Looney and is located in a run on the south bluff of the south branch of Walnut creek, south of the center of the section. It is only some twenty feet deep. The coal is from three to four feet thick and is overlain by about ten feet of dark shale in which there are three layers of calcareous material. One of these lies two feet above the coal and is fine-grained and compact and traversed by many small vertical fissures, which have been filled with calcite and zinc blende. The two other layers are discontinuous and apparently more concretionary, lying respectively two and five feet above the first one. In the lower part of the dark shale a small Orthoceras, a small Chonetes, and fragments of fish teeth were noted. North of the creek in this section several coal banks have also been in operation, one of which lies close to the old bed of the C., R. I. & P. railroad. The old Washington County Coal Company worked several mines in sections 32 and 33 on the south side of the south branch of Walnut creek. A section of one of the shafts used by this company is given by Keyes as follows:*

* Iowa Geol. Surv., Vol. II, p. 395.

IV. SECTION OF A SHAFT OF THE WASHINGTON COUNTY COAL COMPANY. PERLEE.

		FEET.
29.	Drift	33
28.	Sand	3
27.	Clay, dark, shaly	20
26.	Shale, black	6
25.	Coal	3½
24.	Fire clay and shale	10
23.	Coal, shaly	3½
22.	Fire clay	2

The downward continuation of this section as seen in a prospecting hole, beginning under the coal worked, is given by the same author as follows:

		FEET.
21.	Mixed clays	18
20.	Gray shale	10
19.	Sandstone	12
18.	Limestone, gray, impure	8
17.	Sandstone, fine-grained, with brown, flinty partings, laminated, yellowish color	22
16.	Sandstone, bluish, fine-grained, heavily bedded.	20
15.	Sand shale	10
14.	Lime rock, impure	2
13.	Sand shale, gray, fine-grained	8
12.	Clay shale, blue	3
11.	Sand shale, blue, with thin, irregularly bedded, impure sand rock	37
10.	Limestone, impure, buff colored, fragmentary	2
9.	Clays, marly, blue, with small fossils	1
8.	Limestone, impure, bluish	3
7.	Sand shale, light blue, with sandstone partings	7
6.	Limestone, compact, gray, fragmentary	2
5.	Shale, argillaceous, blue and limestone	2½
4.	Shale, argillaceous, gray	3½
3.	Limestone, concretionary, compact, light gray.	4
2.	Marl, gray	2½
1.	Limestone, concretionary, light, with gray clay partings	22

Mr. Keyes refers the lowest ten numbers in the above section to the Saint Louis. Judging from the descriptions alone, the present writer would include in this the lowest nineteen numbers. On some of the shale dumps near the old mines in the southwest quarter of the northwest quarter of section 33 there were observed some lumps of what appears to be a mineralized

charcoal, in which silica fills the pores of the vegetable cell work. Some lumps were six inches in longest diameter. Part of the woody tissue bears the marks of tracheids. There were also some concretions of clay ironstone and large broken lumps of a perfectly black sandstone, consisting of crystalline quartz grains imbedded in a carbonaceous matrix. Old miners say that cakes of this material were sometimes found on the upper surface of the coal seam. All of these shafts were quite shallow, ranging from forty to one hundred feet in depth.

A partial record of the shaft of the Jefferson mine near the station at Perlee is given by Keyes, as follows:*

V. PARTIAL SECTION OF THE JEFFERSON COUNTY COAL COMPANY'S SHAFT NEAR PERLEE.

		FEET.
5.	Shale, gray and clayey above, becoming black, fissile below	15
4.	Coal	3
3.	Fire clay, changing downward into gray clay shales	14
2.	Shale, highly bituminous and coaly in places...	3
1.	Fire clay, exposed	1

On the old dump of this mine there were found some large pieces of silicified trunks of trees, which must have been two feet in diameter. In some of the fragments tracheids could be observed on the woody cells with a weak hand lens. There were also some fissile, gray, calcareous concretions varying from four to twenty inches in diameter and these were quite rich in fossils, such as *Nautilus*, sp. (small), *Orbiculoidea missouriensis* Shum., *Orthoceras rushensis* McChesney (?) *Pleurotomaria illinoisensis* W., *Productus muricatus* N. & P., *P. nanus* M. & W., *Pugnax rockymontana* Marcou, *P. uta* Marcou, *Schizodus alpina* Hall (?), *Straparollus pernodosus* M. & W. On another old shale dump of a mine on the northeast quarter of the northeast quarter of this section some more silicfied wood was noted and also some fossil-bearing concretions of a similar structure containing *Clinopista radiata* Hall (?), *Orthoceras rushensis* McChesney (?), *Orbiculoidea missouriensis* Schumard, *Pleurotomaria illinoisensis* W., *Pleurotomaria*, sp. undet., *Productus muricatus* N. & P., and *Pugnax uta* Marcou.

* Iowa Geol. Surv., Vol. II, p. 397.

The Jefferson County Coal Company once made a drill hole on the upland slope about one-third of a mile east of the center of this section, and an old miner gives the following section of this exploration from memory:

VI. SECTION OF THE JEFFERSON COUNTY COAL COMPANY'S DRILL HOLE.

		FEET
3.	Drift	30
2.	Shales, fire clay, and some seams of coal	70
1.	"Soapstone" and limestone (evidently belonging to the Saint Louis)	100

From this and the previous sections it is evident that the depth of the Coal Measures in this locality is quite limited, not much exceeding one hundred feet. The underlying Saint Louis is exposed in the creeks both to the north and to the east. A large block of limestone was observed in the bed of the creek less than three-fourths of a mile west of Perlee. While it was in such a place that it could not be with certainty said to belong to an undisturbed ledge, it evidently had not been far removed from this. The principal seam, which has been worked, is near the base of the formation and has in places been found to run out against the drift, showing that preglacial erosion extended below the level of the coal in some places. The area on which mines have been worked follows the south branch of Walnut creek a distance of about three miles, being a mile wide. The total area of the land worked is less than one square mile and most of this has not been far from the creek.

Buchanan Township.—The Coal Measures underlie the drift over the greater part of this township, but they rarely come into view owing to the comparatively small depth of the drainage valleys. Excepting some unimportant exposures in Rocky Branch the principal sections are seen on Brush creek. Coal was for some time mined by drifting into the base of the south bluff of this creek, near the northeast corner of the northwest quarter of the southwest quarter of section 10. This is only two miles south and one mile east of Perlee and the coal here is the same as at the latter place. On the old shale banks lumps of the same black sandstone were seen, here with impressions of the bark of trees, and associated with small indurated aggregations of charcoal. There are also the same calcareous concretions con-

taining some of the same fossils as those near Perlee. A quarter of a mile south and a little east of the center of the section, the south bank of the creek exposes two feet of the Saint Louis limestone and underlying this there is:

VII.

		FEET.
4.	Gray shale	1½
3.	Carbonaceous black and fissile shale	2
2.	Fire clay	2
1.	Yellow and irregularly bedded sandstone with imprints of stems and leaves of Stigmaria	1 to 3

In the south bank of the creek, in the northwest quarter of the northwest quarter of section 14, a dark shale is seen which contains some clay ironstone concretions of large size, from two to three feet in diameter. In one of these the upper side consisted of a layer of cone-in-cone while the body was made up of a mass of small spherical concretions of the size of large shot and of a radiate structure. Imbedded in this mass lay some kidney-shaped concretions of black calcareous material containing fragments of brachiopods. Near the center of section 13 the north bank of the creek exposes eight feet of a dark laminated shale in which there are several bands of clay ironstone, some containing a Seminula and *Lingula mytiloides*. Not far from this, on the south bank of the creek, a pile of shale and an abandoned pit indicate the site of an old coal bank. In sections 27 and 35 some explorations by deep wells show that the Coal Measures are absent and that the drift rests on the Saint Louis limestone.

Cedar Township.—Most of this township is no doubt underlain by the Coal Measures, although they have been subjected to quite extensive erosion. On Crow creek, in the central sections the drift extends below the bed of the stream as far down as to the southwest of the center of section 27, below the wagon bridge, where the creek cuts into three or four feet of dark shale in the left bank. This shale contains considerable pyrites and also numerous crystals of selenite, some of which measured four inches in length.

Going up Cedar creek fifteen feet of dark shale is seen in the south bank at the south end of the loop which it makes to the south in the east part of section 35. A band of kidney-shaped

concretions lie at a level a few feet above the base of this bank. In the bed of the creek and under the shale there is a dark, and in places black, coarse sandstone, which is charged with minute grains of pyrites, that apparently had been deposited by infiltration. Some of the sandstone has a calcareous cement of similar origin, and also contains fragments of the Saint Louis limestone. This is no doubt the basal ledge of the Coal Measures resting directly on the Saint Louis limestone. A little south of the center of the northeast quarter of section 35 the east bank of the creek consists of Coal Measure shales and sandstone for a distance of twenty rods. The section is as follows:

VIII. SECTION IN THE LEFT BANK OF CEDAR CREEK NEAR THE CENTER OF THE NE. ¼ OF SEC. 35 CEDAR TOWNSHIP.

		FEET.
5.	Black shale, slightly calcareous and fossil-bearing at the base	8
4.	A layer of calcareous clay ironstone concretions. These concretions vary in size from two inches to nearly two feet in longest diameter. The smaller ones were found to have a core of calcite and zinc blende, while most of the larger ones were checked internally by numerous shrinkage cracks running vertically and filled by the same minerals	½
3.	Black shale, laminated and fissile below, and containing in the uppermost ten inches several fossils such as *Productus semireticulatus* Martin., *P. longispinus* Sow., *P. nanus* M. & W., *P. cora* D'Orbigny, *Spirifer cameracus* Morton, *Chonetes*, sp., *Seminula argentea*, and quite an abundance of a simple cyathopylloid coral measuring about one and a half inches in length. In the lower part there are numerous concretionary cakes of iron pyrites measuring some two inches in diameter with a thickness of about a half an inch	8
2.	Fire clay	4
1.	Sandstone, which at the point farthest south encroaches upon and replaces the fire clay. At the southernmost end a six inch seam of coal separates this sandstone from the dark shale (No. 3) above the fire clay farther north	4

These beds exhibit a gentle syncline, rising rather abruptly at the south end as much as ten feet. This attitude is probably not due to any flexure, but rather a feature of the original deposition, caused by the uneven surface of the underlying Saint Louis. A mile farther west pockets of Coal Measure shales and sandstone are occasionally seen at varying levels on the eroded surface of the lower formation. A dark shale like numbers 3, 4 and 5 in the above section, and with the same kind of concretions, appears in a ravine on the county line near the southwest corner of section 35.

For most of the distance that the creek runs in section 33 its south bank is a continuous exposure of Coal Measures in places resting upon a low ledge of Saint Louis limestone. Thus, near the east line of the section there is seen:

IX. SECTION IN THE BASAL PART OF THE COAL MEASURES IN THE SOUTH BANK OF CEDAR CREEK NEAR THE EAST LINE OF SEC. 33.

		FEET.
5.	Dark shale, weathering to gray with some crystals of selenite	12
4.	Black, bituminous shale containing an abundance of crystals of selenite and occasional cakes of fibrous gypsum. Some crystals and cakes measured five inches in length	1
3.	Hard, gray or grayish-brown sandstone, occasionally black or greenish black from infiltration of pyrites and other materials. Impressions of stems of Stigmaria were noted on the upper surface of the ledge	2
	Unconformity.	
2.	Greenish shale with some thin and uniformly developed laminæ of fine arenaceous material (not well exposed)	4
	Unconformity.	
1.	Brecciated limestone of the Saint Louis stage, with some brecciated siliceous lumps	7

The Coal Measures also appear near the center of the east line of section 32 and in the south bank of Cedar creek in the southeast quarter of section 29, where they may be described as follows:

X. SECTION IN THE SOUTH BANK OF THE CEDAR IN THE SE. ¼ OF SEC. 29.

		FEET.
4.	Black shale	10
	green, stony, arenaceous rock	1½
	green stony, arenaceous rock	1½
2.	Green shale	4
	Unconformity.	
1.	Brecciated limestone of the Saint Louis group.	3

Numbers 2 and 3 in the above are identical with number 2 in the previous section, where they occur under a coarse sandstone. They appear again a little farther to the west, where the bluff shows the following succession of beds:

XI.

		FEET.
6.	Yellow sandstone	3
5.	Yellow shale	3
4.	Coal of the common bituminous kind above, changing into cannel coal below	1½
3.	Fire clay	3
2.	Black shale, becoming highly carbonaceous and bituminous below	6
1.	Green shale extending down to the bed of the creek	4

Above this place the valley of the creek is very wide and the bed rock is not so frequently seen. In section 19 coal has been mined in some shallow shafts, which are now abandoned. The strong mineral taste of the water in several wells indicate that the Coal Measures constitute the bed rock in most of this region.

Black Hawk Township.—In this territory the drainage valleys are shallow and the bed rock was not seen anywhere. That the Coal Measures underlie at least a part of this area is evident from the records of two wells. One of these is in section 6. (See well No. 1 in the table of well records.) It is situated on upland and the first 130 feet went through drift. Below this there were thirty feet of red and black shale. The other well is in the southwest quarter of section 27, and situated on an upland slope. Here there was eighty-five feet of drift and then shale with sandstone at the bottom. In the north the drift no doubt in some places rests on the Saint Louis, but it is probable that more than half of the area is covered by the later formation.

Fairfield Township.—(Excluding the tract in Tp. 71 N., R. X W.) In the three north tiers of sections the valleys are comparatively shallow and field observations on the bed rock were confined to the three south tiers. The Coal Measures underlie the greater part, if not all, of the township. All the deep wells from which records were secured entered either sandstone or shale under the drift. In the north half the thickness may average less than seventy-five feet, but in the south half it evidently averages more than one hundred feet, possibly in places reaching a depth of 150 feet. In the later region some of the wells have gone through several veins of coal, which disappear in short distances and vary considerably in thickness and elevation.

The greatest exposed depth of the formation is seen in the north bank of the Cedar near the center of the northwest quarter

FIG. 61. Exposure of Coal Measure strata in the north bank of Cedar creek, section 32, Fairfield township.

of section 32, where the creek is sapping a nearly vertical embankment almost forty feet high, (Fig. 61), which may be described as below:

XII. SECTION OF THE COAL MEASURES IN THE NORTH BANK OF CEDAR CREEK NEAR THE CENTER OF THE NW. ¼ OF SEC. 32.

		FEET
7.	Soft arenaceous shale with alterating bands of sandstone	7
6.	Gray, cross-bedded and somewhat coarse sandstone	10
5.	A wedge of gray arenaceous shale, thinning towards the west	3
4.	Gray sandstone, slightly cross-bedded and micaceous	7
3.	Coal, thinning to the east and running out to the west, greatest thickness	1½
2.	Fire clay, gray and arenaceous	3
1.	Fire clay and shale (partly concealed)	7

One-fourth of a mile south of the center of section 28 and on the west side of the wagon road where this crosses the old railroad embankment is located the clay bank of the Rainy Bros.' tile factory. The clay which is hauled away from this pit consists of a disintegrated Coal Measure shale, which is obtained by stripping, as it is covered by about fifteen feet of loess and other drift. The bank is at present twenty-four feet high and the material seen is

XIII.

		FEET.
7.	Loess and bowlder clay	15
6.	Coal	½
5.	White fire clay	2
4.	Black shale with some small crystals of gypsum	3
3.	Coal	1
2.	White fire clay	4
1.	Greenish, fine-grained, micaceous sandstone	1

To the north along the creek in this section similar exposures are frequent and coal has been mined here since the early days of the settlement of this county. Several old shale dumps are seen along a ravine which follows the south side of the old railroad in the southwest quarter of the northwest quarter of section 27 and also in the northwest quarter of section 28. The principal coal seam occurs at depths varying from thirty to ten feet below the bottom of the streams and is from three to three and a half feet in thickness. Over it there is a black shale, which contains large septaria occasionally found to contain fossils such

as *Productus costatus* Sowerby, *P. semireticulatus* Martin, and *Spirifer cameratus* Morton. Miners state that some of these septaria are very large and extend down into the coal seam so as to make it necessary to go around them with the entries. Resting on this lower black shale there is some thirty or forty feet of somewhat changeable shale containing thin seams of coal, fire clay and arenaceous material. On top of this there is a concretionary limestone, varying from one to four or five feet. This limestone has a grayish yellow color and exhibits a brecciated structure, especially in blocks which have been subjected to weathering. On a ground surface it is seen to be cut up by an irregular network of small fissures, some of which are too small to be seen by the naked eye. There are also some vermicular, tubular cavities filled with crystalline calcite. It is quite compact and strong and has been quarried to some extent and used in foundations. It is overlain by a black fissile miner's slate, some weathered lumps of which were seen to contain numerous specimens of Leperditia or some similar ostracod, a bone of *Pleuropty clavatus* Cope (identified by Eastman), and several scales, teeth and spines of fishes of unknown relationship.

In one of the wells made on section 28 it is claimed some red ochre was discovered in the shale. A sample, said to have come from this well, was examined by the writer and proved to be a red shale, somewhat ochreous. There may, however, have been some real ochre, as this occurs in small quantities in the same shales farther west.

Liberty Township.—(Including that part of Fairfield township coming within Tp. 71 N., R. X W.) In this region coal mining has been carried on for a long time at different places, though the operations have never been very extensive. At present four "banks" are worked, chiefly during the winter season. The Coal Measures underlie the drift everywhere, excepting some limited areas in or near the bottom lands along Cedar creek and Lick creek. A little south of the center of the northeast quarter of section 24, coal is mined by D. W. Bates in a ravine at a place about forty rods south of the river. The seam is variable in thickness, ranging from three to five feet, and lies at nearly the same elevation as the river bed. Another seam lies from five to

twelve feet above this one in the bluffs at this place, separated from the lower vein by fire clay, shale and some sandstone. At an elevation of about thirty feet some coal is seen overlain by a black miners' slate and several feet of soft sandstone. Some of this coal has also been dug out by drifting into the hills.

Several other old shafts are seen to the southwest. A short distance to the northeast of the center of the southwest quarter of the section a drift is now worked by Bowen and Wilcox in the right bank of a creek. The coal is four feet thick. Above it is a black fissile shale about nine feet thick and then a sandstone. Some explorations have lately been made in this territory and the elevation of the coal seams has been found quite variable, changing as much as forty feet in less than a quarter of a mile. In the west part of section 14 and in section 15 the creek again cuts into the Coal Measures in the south bluff. In the northeast quarter of the northeast quarter of the latter section Mr. Albert Gardner now operates a shaft forty feet deep, close to the river bank. This coal lies eighteen feet below the bed of the creek. It has been mined in several other places close by, this last shaft having been made last year (1900). A general section of the Coal Measures based upon several explorations in the region here is as follows:

XIV. GENERAL SECTION OF THE COAL MEASURES IN THE NE. ¼ OF SEC. 15

		FEET.
9.	Concretionary limestone	1-5
8.	Gray shale	5
7.	Coal	0-3
6.	Fire clay	0-4
5	Sandstone, hard, gray	0-5
4	Shale	30
3.	Slate	1-3
2.	Coal	3
1.	Fire clay and shale	7

South of the wagon bridge east of the center of the north line in the same section there rests on the Saint Louis limestone the same green shale seen in the base of the Coal Measures in Cedar township. In the south bank the following succession was quite apparent:

XV. SECTION IN THE SOUTH BANK OF CEDAR CREEK SOUTH OF THE WAGON BRIDGE IN THE NW ¼ OF THE NE. ¼ OF SEC. 15.

	Feet.	Inches
6. Black, coaly shale associated with a seam of coal which was at one time mined............		
5. Concealed	2	
4. Chocolate, purple and green shale.............	3	
3. An indurated layer of greenish calcareous material, which is a mixture of fine sand and limestone impregnated with pyrites. It has occasional minute black fragments of fish remains. The largest of these was a conical tooth, fluted at base, with a fine polish, and four millimeters long. Frequently the calcareous matrix shows crystalline reflections on vertical fractures. In some places this layer exhibits well formed sun-cracks.............		8
2. Dark green shale containing calcareous septaria about an inch and a half in diameter...	6	
Unconformity, indicated by the yellow, weathered appearance of the joints in the underlying rock.		
1. Limestone of the Saint Louis..................	4	

In section 3 mines have been worked in several places, the principal one having been located under the north bluff southeast of the wagon bridge on the Libertyville road. The old shaft has mostly fallen in and the beds are partly concealed, but as near as it can be made out they are as follows:

XVI. SECTION IN THE NORTH BLUFF OF CEDAR CREEK EAST OF THE WAGON BRIDGE IN SEC. 3.

	Feet.
7. Gray, disintegrated shale, containing occasional crystals of selenite and a seam with large calcareous concretions containing *Spirifer cameratus* Morton, *Productus semireticulatus* Martin, and *Seminula argentea* Shepard......	25
6. Coal	1
5. Sandstone, brown	1-5
4. Black shale	1
3. Coal	1
2. Fire clay and shale	10
1. Coal (not well exposed, near the bed of the creek)	2

The sandstone varies in thickness within a short distance, as do also the other beds.

Northeast from this point, in section 2 as well as in section 3, dark shales are seen in the ravines and there are several old mine dumps. In section 1 several wells have gone into dark shale at depths varying from fifty feet to a hundred feet. To the west, in section 5, there occurs above the shales and rising to some hundred feet above the bed of the creek, a grayish yellow and soft sandstone. It appears in some of the ravines. West of the center of the section it is somewhat fine-grained, very micaceous and in one place overlain directly by loess.

On Lick creek coal has been taken out for many years in the southeast quarter of section 30. Mr. A. J. Zimmerman is now operating a mine on the southeast forty acres in this quarter. The coal is three feet thick and lies twenty feet below the creek valley. The roof consists of a calcareous and fossiliferous shale. Twenty feet above this there is a coarse and micaceous sandstone. Several shafts have also been worked on the northeast quarter of section 31. In the left bank of the creek on the south line of section 32 a black shale is exposed, which contains a thin indurated layer one side of which was covered with imprints of *Aviculopecten occidentalis* Shumard, filled with bright yellow iron pyrites. A short distance up the creek a sandstone ledge is seen in the west bluff about fifty feet above the bottom.

Polk Township.—Thirty feet of dark shale was penetrated in a well in section 2. In some other wells in section 33 and 32 dark shale and coal have been found. In still others a limestone has been found under the drift. The greater part of the township is apparently covered by the Coal Measures, which have perhaps been carried away from most of the territory along the northern border. The average thickness of the formation is probably less than twenty-five feet, but near the south line it must be considerably above this average.

Locust Grove Township.—Nowhere in this township is the Saint Louis exposed. The Coal Measures underlie the drift everywhere, as far as known. In two wells they have been explored to a depth of eighty feet below the base of the drift and in one to about one hundred feet, and have been found to consist mostly of shale with some sandstone and coal.

Along Competine creek shales with occasional seams of coal and of limestone appear in several places, and some coal has been mined at times, as in the southeast quarter of section 21. Near the center of this quarter there is seen in the left bank cf the creek:

XVII. SECTION IN THE WEST BANK OF COMPETINE CREEK, SEC 21.

		FEET.
5.	Black slate	1
4.	Greenish, sandy shale, in places dark, and with septarian nodules	15
3.	Sandstone, greenish, micaceous, calcareous, and shaly, with structures resembling poorly defined fucoids	½-1
2.	Sandy, green shales	8-10
1.	Brecciated concretionary limestone	3

The limestone which lies in the bed of the stream at this place appears at intervals for a mile farther up the creek and a half a mile farther down. Above it are dark and sometimes black and coaly shales. In the south bank of Cedar creek in the southeast quarter of section 28, some very compact blocks of this limestone are seen and it has evidently been quarried. It is here nearly two feet thick and contains occasional small crevices filled with dark zinc blende. Where it has been subject to weathering it is seen in a hand specimen to be composed of a purplish matrix in which lie as if imbedded angular fragments of more compact limestone measuring from one-twentieth to one-half inch in diameter. The contours of these fragments are sharply marked. The rock was otherwise perfectly compact, lacking any semblance of weak fracture planes along the surface of the fragments, breaking across the fragments and the matrix with equal facility. Another specimen showing no weathering did not exhibit such a plainly brecciated structure, but appeared as if made of well defined lumps kneaded together in a broken matrix. Numerous small and fragmentary brachiopod shells were imbedded. On top of this ledge farther up the stream was a black, highly bituminous and fissile shale, and this in turn was overlain by a more greenish shale in which there are some spherical, tough septaria of green color which have internal fissures filled with calcite and which consist of carbonate of iron and are occasionally replaced by lumps of almost pure red ochre.

In a ravine on the northwest quarter of the northeast quarter of section 25, Mr. George Stever has a stone quarry in some ledges of sandstone. Several outcrops in the hills at this place show the following succession:

XVIII. SECTION IN A RAVINE IN THE NW. ¼ OF THE NW. ¼ OF SEC. 25.

		FEET.
4.	Sandstone, micaceous, yellowish gray, more or less disintegrated	20
3.	Sandstone, gray, coarse, hard and micaceous, in heavy ledges, containing occasional balls of clay from one to five inches in diameter. A sample of the quarry rock consisted of mainly clear quartz grains, imbedded in a copious calcareous matrix. There was also some mica, a few calcareous grains, some magnetite (?), and some green quartz. The quartz grains were angular and measured mostly from one-eighth to one-half millimeters in diameter, many showing crystal faces due to secondary enlargement	5
2.	Cross-bedded, yellowish-gray, micaceous, disintegrated sandstone	8
1.	Laminated sandy shale, mixed with black carbonaceous material	3

Considerable rock of a similar character has been quarried in some ravines east of the center of section 25. In one of these ravines beds of considerable depth were noted as follows:

XIX. SECTION EAST OF THE CENTER OF SEC. 25.

		FEET
4.	Coarse, gray, micaceous sandstone, with a calcareous matrix	12
3.	Same as above, but whiter and in one ledge	2
2.	Sandstone, more thinly bedded, interlaminated with shale and having imprints of stems of trees	4
1.	Cross-bedded, blue and coarse micaceous shale	20

The top of this sandstone must rise not far from a hundred feet above Cedar creek. The finer shaly rocks beneath it have been excavated for filling a long railroad embankment east of Krum. At this place they were quite disintegrated and soft. This sandy phase of the Des Moines outcrops on the north side of the valley and has furnished small quantities of stone in Rocky run in section 3.

Des Moines Township.—Excepting a small area on Lick creek in section 25 this whole township is underlain by Coal Measure rocks. The sandstone noted in the south part of Locust Grove township appears in sections 5 and 8 and has been quarried in some places, furnishing a fair rock for foundations. One ledge was seen to be unusually coarse-grained. Most of the stone is in thin beds, in ledges from four to eight inches. In the valley of Black creek coal has been mined for many years in different places. One mine now running is owned by Caves Bros. and located about twenty rods south of the center of the north line of section 30. The mine is shallow, less than twenty feet deep, but the seam of the coal is fully four feet thick. In some lumps of the roof shale *Lingula mytiloides* was observed, and also impressions of some Lepidodendron. In the south bank of the creek the following strata appear:

XX. SECTION IN THE SOUTH BANK OF BLACK CREEK NEAR THE CENTER OF THE SW. ¼ OF THE NW. ¼ OF SEC 30

		FEET.
3.	Fossiliferous, bluish black limestone containing a large *Seminula argentea* Schl., *Spirifer opimus* Hall, a Derbya, some bryozoa, and many joints of crinoid stems, some of which were very large	1
2.	Gray shale with occasional concretions	6
1.	Shale, black, and changing to coal below	4

The limestone appears again in the same place farther down the creek. It is there cut by straight and vertical joints into large rhomboidal blocks and in places it has imbedded grains of coarse sand, together with fossils. It also exhibits lenticular thickenings, as if composed of concretions which have become continuous with their edges, and contains some peculiar flow structures which resemble the fucoids known as *Spirophyton cauda-galli* Hall. It is evident that the Coal Measures have a greater thickness in this region than anywhere else in the county and that there are two or three veins of coal, one of which is quite extensive and ranges up to five feet in thickness. Among other places where this has recently been mined is on the southwest quarter of the northwest quarter of section 32 (Frank Cloke's bank), on the northwest quarter of the southeast quarter of section 20 (Wm. Gonterman's bank), and on the northwest quarter

of the southwest quarter of section 29 (James Gonterman's bank). In a ravine crossed by the wagon road going east and west through the southwest quarter of the northwest quarter of section 28, and on the north side of this road the following strata were seen:

XXI.

		FEET.
5.	Drift	15
4.	A seam of calcareous septaria	1½
3.	Gray, light shale or marl with many fossils such as *Bellerophon carbonaria* Cox, *Chonetes mesolobus* N. and P., *Derbya crassa* Meek and Hdn., *Pleuromaria conoformis* Worthen, *Productus muricatus* N. and P., and *P. semireticulatus* Martin	5
2.	Black sandstone filled with imprints of leaves.	1½
1.	Coal and fire clay	1

The top of this exposure lies at an elevation of at least eighty feet above the bed of Black creek to the southwest. As the Coal Measures are known to extend to some depth below the bed, they must have a considerable development in the region. The average thickness for the township will probably not fall much below a hundred feet. Nor is there any doubt that productive seams of coal have a greater extent than the present explorations show.

Thickness of the Des Moines.—On the basis of the field observations as well as of the well records, approximate estimates can be made as to the thickness of the Coal Measures in thè several townships. It will be seen that they average less than forty feet for the entire county and that they are heaviest in the southwestern townships.

PLAT OF ESTIMATED AVERAGE THICKNESS OF THE DES MOINES IN THE SEVERAL TOWNSHIPS OF JEFFERSON COUNTY (IN FEET.)

Polk 20	Black Hawk 15	Penn 30	Walnut 10
Locust Grove 80	Fairfield 75	Buchanan 20	Lockridge 40
Des Moines 50	Liberty 50	Cedar 20	Round Prairie 20

It should be remembered that the figures given are estimates and that since both the upper and the lower limits of the formation conform to ancient erosion contours there are apt to be great local variations in its development. It is believed that the maximum development of the formation will not exceed three times the figures given, while at the same time it is known that excepting Fairfield and Locust Grove townships, the minimum limit is zero; that is, the Coal Measures have been entirely removed at some point in nearly all the townships.

In the main the Coal Measures consist of shales and sandstones. With these are associated some seams of limestone, coal and fire clay. All of these rocks vary greatly in appearance and run into each other by all possible gradations. The shales may be sandy, calcareous, or coaly; the sandstones may be shaly, calcareous or carbonaceous; and the limestones are occasionally sandy, quite often bituminous, and sometimes shaly. Representing as they do the first sediments in an advancing sea, such changes are quite natural. The very base which rests on the Saint Louis limestone is most variable. Probably in the greater number of

cases this consists of sandstone. In many instances it is a shale, and sometimes it is coal and fire clay. As compared with other regions it may be said that there is an absence of coarse materials in the base of the Coal Measures here. Earlier observers have noted the fact that separate beds run out in short distances in this region. No single seam of coal has been worked over any extensive region and it may be questioned if any identical seam has been traced for a distance of more than three miles. Nevertheless, there are indications that there may be discontinuous occurrences of beds of identical appearance and contemporaneous deposition in different places. This may be accounted for by supposing a considerable irregularity of the ancient shore line, allowing the making of synchronously similar as well as dissimilar deposits. The writer believes that the coal mined by Caves Bros. in section 30 of Des Moines township, is to be correlated with that mined by Mr. Smith in section 27 in Lockridge township, and at the same time it is quite evident that this seam has never been continuous between the two places. There can be no doubt that the limestone quarried in the northeast quarter of section 28 in Fairfield township is to be correlated with that occurring in the south bank of Cedar creek in the northeast quarter of section 28 in Locust Grove township, while to all appearances the two areas of this limestone are separated by an intervening arenaceous phase of the formation. The same limestone occurs again some six miles northwest of Eldon, in Wapello county. As an instance of similar import may also be mentioned the recurrence at distant places of a cannel coal at elevations of from twenty-five to fifty feet from the base of the Coal Measures. This is always associated with some bituminous coal of the usual kind. There also recurs at about the same horizon a sandy, shaly and coaly limestone, which contains imprints of a structure resembling *Spirophyton cauda-galli*. The writer has observed this rock in the base of the Coal Measures at several places both in Illinois and Iowa, and has noted that it frequently runs out and is replaced in a horizontal direction by entirely different rocks.

Like most old sedimentary rocks this formation has acquired some secondary characteristics, chiefly through transportation and replacement of some minerals by the ground water. It is

thus found that the grains in the sandstones in the lower part of the formation have been increased in size by secondary enlargement, and instead of being rounded usually show small crystalline faces which may glitter in the sunlight. This increases the roughness and grittiness of the rock, which is a constant and characteristic feature of the basal sandstone, and serves to distinguish it from the underlying sandstones of the Springvale beds. An occasional feature of the lowest one or two feet of the basal sandstone, and which has been noted only when this rests on limestone, is that it has had its interstices filled with iron pyrites. This gives it a black, dark gray or greenish gray color. In the shales we find that the segregation of a few minerals has resulted in the growth of crystals or concretions of various kinds. Gypsum crystals are quite frequent, varying from sizes that are barely visible to crystals five inches long. Calcareous layers have frequently gathered into concretions. In the same basin the concretions of the same seam are apt to exhibit quite constant characters as regards size, shape or internal structure. The most common mineral in these concretions is carbonate of lime with a greater or less admixture of carbonate of iron. Quite frequently these concretions are cut up by shrinkage cracks, which have been filled by crystalline calcite or else by sphalerite. In blue or greenish shales, which are rich in ferruginous materials, the concretions usually consist of a stony siderite, which on weathering turns into red ochre. Lumps of almost pure red ochre of this kind were noticed in a green shale in the banks of the Cedar creek in section 28 in Locust Grove township.

LIST OF FOSSILS OBSERVED IN THE COAL MEASURES IN JEFFERSON COUNTY BY J. A. UDDEN

	From the roof shale in W. C. Kmish Coal Co.'s shaft in Sec. 27, Lockridge	From the concretions in the roof shales on dumps near Perlee.	From Brush creek in the Se. ¼ of section 10, Buchanan	From Brush creek near the center of section 13, Buchanan	From Cedar creek near center of Nw. ¼ of section 15, Cedar.	From near east line of section 33 in Cedar creek, Cedar	From section 28, Fairfield	From the Sw. ¼ of the Nw. ¼ of section 28, Des Moines	From the Sw. ¼ of the Ne. ¼ of section 30, Des Moines	From Laven Brothers' mine, section 30, Des Moines	From bank of Lick creek near the south line of section 18, Des Moines	From bluff near wagon bridge across Cedar creek in section 3, Liberty.
Plants—												
Gymnosperms (silicified wood, tracheids)		†										
Lepidodendron aculeatum Sternb	†											
Lepidodendron distans Lesq	†											
Lepidodendron, sp										†		
Lepidophyllum (spores)	†											
Sigillaria leptoderma Lesq	†											
Spirophyton(?)									†			
Stigmaria, sp			†			†						
Animals—												
Cyathophylloids					†							
Crinoids (stems)									†			
Bryozoa									†			
Brachiopods												
Chonetes mesolobus N. & P								†				
Chonetes, sp		†			†							
Derbya crassa M. & H								†				
Derbya, sp									†			
Lingula umbonata Cox	†			†						†		
Productus cora d'Orbigny					†							
Productus costatus							†					
Productus longispinus Sow					†							
Productus muricatus N. & P		†						†				
Productus nanus M. & W		†			†							
Productus semireticulatus Martin					†		†	†				†
Pugnax rockymontana Marcou		†										
Pugnax uta Marcou		†										
Seminula argentea					†				†			†
Seminula, sp				†								
Spirifer cameratus Morton					†		†					†
Spirifer opimus Hall									†			
Lamellibranchs												
Clinopistha radiata Hall (?)		†										
Schizodus alpinus Hall (?)		†										
Avicalopecten occidentalis											†	
Gasteropods												
Bellerophon carbonaria Cox								†				
Orbiculoidea missouriensis Schumard		†										
Pleurotomaria conformis W								†				
Pleurotomaria illinoisensis W		†										
Pleurotomaria, sp		†										
Straparollus pernodosus M. & W		†										
Cephalopods												
Nautilus, sp		†										
Orthoceras rushensis McChesney (?)		†										
Arthropods												
Leperditia, sp							†					
Vertebrates												
Teeth of fishes		†										
Pleuroptyx clavatus Cope (?)							†					

Correlations.—It is in every way apparent that the deposits containing the coal make up the base of the Coal Measures. Sandy members in this complex, and also the black shale associated with the coal seams, contain fossil plants of various kinds.

Higher up and in the calcareous seams these give place to brachiopods and mollusks, indicating a change to a more open sea.

Chester Shales.—With the Coal Measures there have been described in the foregoing some green shales that rest on the Saint Louis and come in below a stigmaria-bearing sandstone at one place and below a black shale at another, on Cedar creek. Concerning these shales the writer is in doubt whether they are to be referred to the Coal Measures or not. The evidence as to where they really belong is not conclusive. They have already been sufficiently described, being number 2 in section IX, numbers 2 and 3 in section X, numbers 1 and 2 in section XI, and numbers 2, 3 and 4 in section XV, ranging, as will be noticed, from about four to ten feet in thickness. They exhibit a uniformity of development which is unlike anything that we are accustomed to find in the Coal Measures. Though the different points at which these beds occur are fully six miles apart, a thin seam of more indurated calcareous and arenaceous material apparently maintains itself in all the exposures, for it may be seen at an elevation of about five feet from the base of the shales at each place where this level comes into view. The only fossils found belong to this seam and consist of small fragments of fish teeth and scales. It was also seen to bear the marks of sun-cracks in one place. In all of these respects it is unlike the shales of the Des Moines. The whole deposit also has a deeper bluish green color than the latter. An unconformity is indicated with the deposits above, but the exposures are unsatisfactory, and it may be an unconformity in the bedding, entirely local and of no significance. Lying between the Saint Louis, with which they are plainly unconformable, and the Des Moines, these shales occupy the horizon of the Chester formation known a hundred miles farther south. This formation consists largely of green shales in its northernmost extension. Possibly there was a local submergence here somewhat preceding the submergence which brought the Des Moines, and this may have been coincident with a part of the time represented by the Chester deposit farther south. The question must be left undecided at present, and local students of the Coal Measures might profitably attempt a more satisfactory solution of the problem of the equivalence of these beds.

EROSION INTERVAL.

After the Coal Measures were deposited the bottom of the Carboniferous sea was elevated and the new land was subjected to general erosion, at least during the Triassic and Jurassic periods, and during the Tertiary age. If a submergence occurred in the Cretaceous time, the deposits of the Cretaceous sea were all removed afterward during the Tertiary age, when this region was doubtless above water. At the end of the Tertiary the land was in the main such as it would appear today, if the drift were removed. Some of the largest of the present drainage lines were already marked out, for the bed rock is still seen to rise in their sides under the drift. Possibly some of their present tributaries were also in existence at that time. The deep drift in the basin of Crow creek suggests its preglacial existence. Compared with regions lying nearer to the great rivers of the interior the preglacial topography of this county is less diversified. No deep buried channels have been found. The greatest vertical difference in the elevation of the bed rock as observed in twenty-seven wells is 110 feet. Apparently the old Tertiary plain had no greater relief than the surface of the present land. A table of these wells, with records of the materials in each case, is inserted here.

WELL RECORDS IN JEFFERSON COUNTY.

Black Hawk Township.

NO.	OWNER AND LOCATION.	SITUATION.	ELEVATION OF CURB	DEPTH.	MATERIALS PENETRATED.	ELEVATION OF TOP OF BED ROCK
1	T. A. Webb, Nw. ¼ Sec. 6.	Upland.	800	160	Loess and yellow bowlder clay, 60 ft.; dark bowlder clay, 70 ft.; red shale, 10 ft.; some black shale.	670
2	——— ——— ———, Sw. ¼ Sec. 27.	Slope.	760	161	Yellow bowlder clay, 50 ft.; dark bowlder clay with inclusions of brown sand, 35 ft.: below this there was shale and then 4 ft. of sand rock at bottom.	675

Buchanan Township.

NO.	OWNER AND LOCATION.	SITUATION.	ELEVATION OF CURB	DEPTH.	MATERIALS PENETRATED.	ELEVATION OF TOP OF BED ROCK
3	T. H. Clover, Sw. ¼ Sec. 27.	Upland.	780	186	Yellow and bluish loess and gumbo, 25 ft.; red bowlder clay and gravel, 20 ft.; dark bowlder clay to bottom	594

Buchanan Township—Continued.

NO.	OWNER AND LOCATION	SITUATION.	ELEVATION OF CURB.	DEPTH.	MATERIALS PENETRATED.	ELEVATION OF TOP OF BED ROCK
4	I. P. Manatry, Sw. cor. Sec. 35.	Upland.	775	240	Drift, 129 ft.; limestone, 30 ft.; bastard rock and sandstone, 51 ft., limestone, soft and bluish in the lower part, 30 ft.	646

Des Moines Township.

NO.	OWNER AND LOCATION	SITUATION.	ELEVATION OF CURB.	DEPTH.	MATERIALS PENETRATED.	ELEVATION OF TOP OF BED ROCK
5	E. McCleary, Nw. ¼ Sec. 1.	Upland.	760	230	Sandy loess, 20 ft.; yellow and then dark bowlder clay, 44 ft., limestone, 2 ft., "dark material" (probably shale), 32 ft., limestone, 4 ft.; gritty shale, 20 ft., yellow arenaceous rock, 108 ft., water salty	606

Fairfield Township.

NO.	OWNER AND LOCATION	SITUATION.	ELEVATION OF CURB.	DEPTH.	MATERIALS PENETRATED.	ELEVATION OF TOP OF BED ROCK
6	F. J. Shearer, Nw. ¼ of Sw. ¼, Sec. 14.	Upland.	785	165	Loess, 10 ft., "joint clay" or gumbo, 25 ft., red bowlder clay, 30 ft., dark bowlder clay, 30 ft.; white shale, 20 ft., some arenaceous material below this.	645
7	J. F. Seahill, near center, Sec. 17	Upland.	780	145	Loess and yellow bowlder clay, 60 ft.; sand and gravel, 10 ft., dark bowlder clay, 40 ft., sandstone in bottom; water with a mineral taste.	670
8	G. W. Ball, near center of Sw. ¼ Sec. 19.	Upland	780	186	Drift, 95 ft., sandstone, some "dark rock" and some arenaceous material, with some coal and black shale, 91 ft.	685
9	Rainy Bro's Tile Factory, Fairfield	Upland.	775	170	One foot of coal in the lower part of the well.	630
10	C. W. Whitam, Ne. ¼ of Se. ¼, Sec. 28	Upland	750	230	Drift, 120 ft.; black shale, fire clay and several small seams of coal alternating, 45 ft.; coal "6 ft.", alternations of shale, sand rock and fire clay, with dark sandstone below, 59 ft.	
11	A. Freshwater, Sw. ¼ Sec. 23.	Upland	750	237	Drift, 120 ft., shale, fire clay, soft sandstone and small coal seams, 46 ft.; thicker seam of coal, some 4 ft.; fine, gray shale, 7 ft., fine, red shale, 18 ft., sandstone, 32 ft. (Statements as to this record contradictory.)	630
12	J. B. Steever, Se. ¼ Sec. 28.	Upland	750	185	Drift, 80 ft., shale and fire clay, with thin seams of coal, 50 ft.; sandstone, 20 ft., seam of coal, 4 (?) ft.; limestone in bottom of well.	670
13	D. W. Manning, Se. ¼ Sec. 31.	Upland.	750	200	Drift about 100 ft.; dark pyritiferous sandstone, 20 ft.; common sandstone, 80 ft.	650

Liberty Township.

NO.	OWNER AND LOCATION	SITUATION.	ELEVATION OF CURB.	DEPTH.	MATERIALS PENETRATED.	ELEVATION OF TOP OF BED ROCK.
14	L. Howard, ¼ mi. S. of center N. line Sec. 1.	Upland slope.	750	185	Four wells from 185 to 200 feet deep. Reports as to nature of strata very contradictory, probable nature of ground as follows: Drift, 115 ft.; "quartz rock" (siliceous sandstone?), 60 ft.; other sandstone, 8 ft. Lower part of well said to consist of alternating dark and light layers of hard rock, giving some high and some low assays of gold, silver and copper.	635

Locust Grove Township.

NO.	OWNER AND LOCATION	SITUATION.	ELEVATION OF CURB.	DEPTH.	MATERIALS PENETRATED.	ELEVATION OF TOP OF BED ROCK.
15	T. Z. Gillett, Sw. ¼ Sec. 3.	Upland.	780	218	Loess and yellow bowlder clay 60 ft.; dark bowlder clay 80 ft.; black shale, with much pyrites 40 ft.; bluish black carbonaceous material 8 ft.; sandstone, shale and fire clay 30 ft.	640
16	J. D. Baird, Se. ¼ Sec. 4.	Upland.	780	200	Drift 140 ft.; coal in lower 50 feet of well.	640
17	T. W. Gotbie, Se. ¼ Sec. 5.	Upland slope.	740	[illegible]	Yellow drift 30 ft.; dark bowlder clay 60 ft.; gravel 18 ft.; black shale 80 ft.	632
18	L. A. Patterson, Se. corner Sec. 10.	Upland.	750	160	Loess 20 ft.; gumbo 10 ft.; yellow bowlder clay 40 ft.; dark bowlder clay 60 ft.; sandstone mostly fine but somewhat coarser below 40 ft.	630
19	T. W. Hill, Sec. 31, near depot at Batavia.	Creek bottom.	700	200	Some gravel at about 60 feet below surface. Thirty inches of coal at 115 feet below surface. A hard sandstone at the bottom.	6[illegible]

Penn Township.

NO.	OWNER AND LOCATION	SITUATION.	ELEVATION OF CURB.	DEPTH.	MATERIALS PENETRATED.	ELEVATION OF TOP OF BED ROCK.
20	J. Pascin, corner Sec. [illegible]	Upland.	780	125	Loess and yellow bowlder clay 60 ft.; some sand; dark bowlder clay contd to 120 feet below curb of well; limestone with some sand 5 ft.	6[illegible]
21	M. Poim, Sw. ¼ Sec. 24.	Upland.	75[illegible]	[illegible]	Loess and yellow clay 50 ft.; dark bowlder clay 5 ft.; gravel 2 ft.	7[illegible]

Polk Township.

NO.	OWNER AND LOCATION	SITUATION.	ELEVATION OF CURB.	DEPTH.	MATERIALS PENETRATED.	ELEVATION OF TOP OF BED ROCK.
22	L. K. Walker, Sw. cor. Sec. 2.	[illegible]	80[illegible]	50	Drift and some clay 20 ft.; dark shale 5 ft.; limestone with chert [illegible]	6[illegible]
23	Geo. E. Bates, W. ½ Sec. 20.	Upland.	8[illegible]	10[illegible]	Limestone with some chert at [illegible] ft.; sandstone at [illegible] ft. continuing with changes of texture and hardness to 180 ft. No signs of coal.	7[illegible]

Polk Township—Continued.

NO.	OWNER AND LOCATION.	SITUATION.	ELEVATION OF CURB	DEPTH.	MATERIALS PENETRATED.	ELEVATION OF TOP OF BED ROCK.
24	T. R. Smith, Se. ¼ Sec. 20.	Upland.	780	79	Dark drift from 70 to 75 feet below surface; shale about 3 ft.	705
25	A. T. Downey, W. ½ Sec. 33; (just E. of Abingdon.)	Upland.	760	75	Drift, 70 ft.; shale and coal in bottom.	690
			Round Prairie Township.			
25	————————, Se. ¼ Sec 28.	Upland.	740	246	Yellow clay, 40 ft; dark clay, 50 ft.; not known, 12 ft.; limestone, 98 ft.; chert, 8 inches; 2 ft shale and other material, 15 ft., "hard, yellow, fine sand rock with balls of hard material," 40 ft.	640
			Walnut Township.			
27	C. Schaffer, E. ½ Sec. 16.	Upland.	720	240	Drift, 60 ft; "rock and shale," 180 ft.; hard rock, (= limestone?) in bottom.	660

The Pleistocene.

Subsequent to the Tertiary age extensive glaciers invaded this region from the north and laid down sheets of bowlder clay which now cover most of the north central states. With the overlying loess and associated gravels and sand this bowlder clay is commonly called the drift. In Jefferson county the average thickness of the drift is 115 feet, including the loess and the bowlder clay and disregarding local reduction by subsequent erosion. It exceeds this depth in Buchanan and Cedar townships and falls below it in Walnut and Des Moines townships.

Associated Gravels.—In the eastern part of the county a few places were noted where gravels and sands rest on the bed rock and are covered by bowlder clay. The most extensive exposure of this kind is at the southwest corner of section 1, Walnut township, in the south bank of a ravine, which is fed by a number of springs that issue from the gravel at intervals for a distance of some thirty rods. The deposit is fully twenty feet thick and lies at an elevation of about 100 feet above Skunk river. To the west it is covered by bowlder clay and for a mile in this direction

there are wells in which the water comes from the same gravel, and has a strong mineral taste. The deposit is highly ferruginous and almost ochreous, brownish yellow in color, and in places cemented into a soft stone. The lower part is a gravel, but the upper fifteen feet is an evenly bedded, laminated sand of variable texture, with here and there silty seams. Deposits like this, but more silty, were noted in the base of the drift at two other localities in this region; on the wagon road at a shallow draw near the center of the west line of the northwest quarter of section 12 in Walnut township and at the base of the bluff in the wagon road which leads down to the ford across Skunk river in the east half of the southeast quarter of section 11 in Lockridge township. Some indurated brown gravel or sand was again noted in the south bank of a ravine above the wagon bridge near the southeast corner of section 24 in Round Grove township. The section at this place was as follows:

		Feet
4.	Bowlder clay (interbedded with number 3)	
3.	Yellow, quite evenly bedded sand and gravel	[illegible]
2.	Brown sandstone, hard enough to be used for building stone	[illegible]
1.	Slightly indurated brown sand and gravel	[illegible]

The same gravel occurs in the two next streams which [illegible] the east boundary of the county to the south of this place and it was also noticed resting on the red rock in two ravines running into Cedar creek in the southwest quarter of section [illegible].

The age of this gravel is problematical. Judging from its position it may be of preglacial or Tertiary age. But it can as well be glacial. In favor of the latter view is the fact that it contains a great deal of Archaean material and against it the fact that among 300 pebbles which were examined none were found to be scored, and further that the proportion of different rocks seems very variable at different localities. Glacial gravels are usually composed of the same materials in quite constant proportions in the same region. In real Tertiary [illegible] gravels we would be apt to find a greater diversity in the [illegible] of materials along different drainage lines. The degree of [illegible]tion and the thoroughness of oxidation and [illegible] a considerable age for these gravels. [illegible]

almost entirely absent. Some unique pebbles testify to this extensive leaching. On section 1, in Walnut township, the gravel contains some pebbles of limonite, which are hollow. They are of the shape and size of an empty shell of a hazel nut. Presumably these limonite shells have been formed as incrustations around calcareous pebbles, which afterward have been leached out by slow percolation through the crust, leaving this empty. The following table gives the proportion of the different materials represented among pebbles measuring about one-half inch in diameter for four different localities:

KINDS OF ROCKS	Section 1, Walnut.	Section 12, Walnut	Section 11 Lockridge.	Section 24, Round Prairie	Average.
Quartz	13	17	11	[illegible]	13
Chert	29	44	48	2	31
Granite	22	15	3	36	19
Diabase? (mostly brown and decayed)	9	7	3	13	8
Greenstone (in part schist)	9	4	8	52	18
Hornblende rock	1	0	6	0	2
Quartzite	2	8	5	2	4
Dolomite? (all decayed)	3	0	5	0	2
Sandstone	2	2	6	[illegible]	3
Limonite	9	7	3	0	5
Agate	1	0	1	.....	½
Black felsite	.....	1	.....	.....	tr
Magnetite	.....	1	.....	.....	tr
Coal Measure rock	.....	.....	.....	2	½

If these gravels are to be regarded as belonging to the glacial deposits they may belong either under the lowermost or Albertan drift or above this under the Kansan. The overlying bowlder clay resembles the Kansan, but it is in a locality where the earlier bowlder clay may have been removed, before the Kansan drift came. Hence, it is impossible to determine whether these gravels are Tertiary, Albertan or whether they are to be correlated with the Aftonian.

The Bowlder Clays.—There are two bowlder clays in this region, deposited at two different times: the Albertan, or pre-Kansan, and the Kansan. The Albertan rests on the bed rock or on a thin seam of gravel or sand. It is dark bluish gray or almost black and quite hard and tough. Some well makers in

this county even call it "hardpan," which is a misnomer. It frequently contains pieces of wood of gymnospermous trees and angular fragments of coal. On the uplands this bowlder clay averages sixty feet in thickness, and is seldom less than thirty feet or more than seventy. Here as elsewhere it is apt to contain seams or pockets of yellow sand and occasional streaks of peaty material, especially near the bottom and near the top. Small crystals of gypsum were observed in one place. It is not often seen in typical exposures along the streams, but is always found under the uplands in making wells.

FIG. [illegible]. Kansan drift [illegible] one mile west of Fairfield.

On top of the Albertan is a yellow or light gray bowlder clay which has been called the Kansan. This is sometimes sharply marked off from the Albertan either by a decided change in color or else by intervening streaks or pockets of yellow sand. This must be regarded as an equivalent of the Buchanan gravels. More often the two clays merge gradually into each other, the change taking place through several feet of vertical extent. The Kansan drift seldom if ever contains any pieces of wood or of coal. In places it is somewhat sandy and open to the ground water, while at other places it is changed above into a gray clayey

and slippery earth called "gumbo," which is almost impervious to water. From this all calcareous materials are removed. Near the east line of section 29 in Fairfield township the new railroad cuts expose fifteen feet of such gumbo, under the loess. The embankments have slid down on the road bed and it has been found necessary to lay tile to drain the ground more promptly. The leaching of the Kansan is quite variable in depth, changing, in some places, from four to twelve feet in a few rods. This appears to be due to difference in texture, or perhaps also to difference in drainage. In a few localities the Kansan drift was sandy and obscurely stratified about ten feet below its upper surface. It frequently contains calcareous concretions at the base of its upper leached part.

To secure if possible some evidence bearing on the probable difference of origin of the two bowlder clays a study was made of the frequency of different kinds of rocks among the erratics of each. About one thousand pebbles, collected in lots of one hundred from ten localities in each bowlder clay, were classified and tabulated. It was then found that the Keweenawan rocks, such as hornblende rock, diabase, gabbro, epidote, a red arkose, and also chert, were slightly more frequent in the Kansan and that Huronian rocks such as greenstone, some schists, slate, jaspilite, syenite, and Paleozoic rocks, such as dolomite, limestone, clay ironstone, shale, pyrites and coal, were more common in the pre-Kansan, or Albertan drift. Granite, quartz, quartzite, sandstone and Cretaceous pebbles were present in about equal quantities in both tills. This difference, though slight, may be said to corroborate the evidence found elsewhere that the Albertan and the Kansan till were laid down by two different glacial sheets, that had somewhat divergent lines of transportation, the former coming more directly from the north and the latter more from the northeast, where the Keweenawan rocks predominate. The greater abundance of local and Paleozoic rocks in the lower drift is most likely due to the fact that much of the Kansan must consist of the Albertan ground over a second time, when the softer sedimentary rocks would suffer more attrition than the more durable igneous and metamorphic erratics. To see to what different extent different rocks suffered reduction in the glacial mill

we need only ascertain the variations of percentage which the several rocks make in assemblages of erratics of different sizes. The result of some observations of this kind on the erratics in this county are given in the table below:

TABLE SHOWING THE PERCENTAGE OF DIFFERENT KINDS OF ROCKS AMONG ERRATICS OF DIFFERENT SIZES IN THE BOWLDER CLAYS OF JEFFERSON COUNTY.

KINDS OF ROCKS.	AVERAGE DIAMETER (IN INCHES) OF ERRATICS.						
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Quartz				[illegible]	1	[illegible]	[illegible]
Granite	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Greenstone		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Hornblende rock		[illegible]	[illegible]	[illegible]		[illegible]	1
Schists			[illegible]	[illegible]	[illegible]	[illegible]	1
Syenite			[illegible]	[illegible]		[illegible]	
Slate						[illegible]	
Jaspilite				[illegible]		[illegible]	[illegible]
Gneiss		[illegible]	[illegible]	[illegible]			
Diabase and gabbro	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Other dark eruptives			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Epidote						[illegible]	[illegible]
Quartzite			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Arkose (Keweenawan sandstone?)			[illegible]	[illegible]	[illegible]		[illegible]
Dolomite		[illegible]		[illegible]	[illegible]		[illegible]
Chert			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Limestone		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Shale							[illegible]
Coal						[illegible]	
Pyrites							
Clay ironstone concretions				[illegible]	[illegible]	[illegible]	[illegible]
Sandstone			[illegible]	[illegible]	[illegible]	[illegible]	
[illegible] rock					[illegible]	[illegible]	[illegible]

It will be noticed that the [illegible] granite, with a few consisting of diabase and gabbro [illegible] largest bowlder seen in the county [illegible] feet and lies in a [illegible] section [illegible] granite [illegible] all [illegible] in the same [illegible] in the drift in this county [illegible] in [illegible] the former weighing [illegible] pounds and the other about eight [illegible]

Loess.—The bowlder clay is [illegible] covered with loess which averages about [illegible] feet in depth in [illegible]

the reports of well makers it appears somewhat heavier than this on the upland divides, but on the edge of the slopes it is often only eight or ten feet. It usually contains no calcareous materials. These appear to have been leached out. "Loess-kindchen" are very rarely found. Fossils were assiduously looked for, but none were seen. In the east bluff of Skunk river just across the east boundary of Walnut township and near the town of Coppack in Henry county, this formation is quite different; it is considerably thicker, somewhat more coarse and open in texture, it is calcareous and contains small fossil snails. This same phase runs northwest in the bluffs and no doubt underlies an acre or two of land in the extreme northeast corner of Jefferson county, though this could not be verified by direct observation. On the low edge of upland which forms the east bluff of Cedar creek east of the Chicago, Burlington and Quincy railroad bridge in Locust Grove township, the base of the loess exposed along the road-bed contained a thin dark seam, in which some spherical nodules of impure wad were imbedded. Nodules of this kind are occasionally found in boggy places in the upland loess in Illinois.

Alluvial Deposits.—These form the terraces and bottom lands along the the streams. The former consist of pebbly, bedded clays and sands generally concealed under a thin mantle of loess. The clays are usually calcareous. Owing to the general presence of a loess-like mantle they are seldom exposed. On the bottom lands yellow sand usually lies under a yellow silt. The latter is frequently like loess in texture and varies from five to fifteen feet in thickness.

A Pleistocene Fossil.—In the bed of Walnut creek, where it follows a rocky cliff in the west half of the southwest quarter of the northwest quarter of section 28 in Walnut township, Mr. Josia Bates some years ago found the lower jaw of *Elephas americanus*. Both molars were well preserved and the entire specimen weighed fifty pounds. From sketches taken by the writer, Professor Calvin infers that the specimen is from an animal slightly undersized, between fifty and sixty years of age. To what part of the drift it belongs is not evident.*

Geological Structure.

The several formations lie almost horizontally in Jefferson county. If there is a general dip to the southwest, it is small and the amount cannot be accurately estimated. Some small local dips are known. The Saint Louis limestone, especially in the upper beds, is often affected by some dome like flexures, which commonly are only a few rods in diameter, and where the center is elevated two or three feet above its height around the dome. In the extensively brecciated ledges a fault with a downthrow of four feet was noted in one exposure in the north part of [illegible] ridge township. Small deformations of this kind are probably incident to underground collapsed caverns and to brecciation and dolomitization of the Saint Louis beds.

Joints.—The bearings of sixty-seven joints in the Saint Louis limestone were taken in different parts of the county. [illegible]

[illegible]

[illegible]

[illegible]

and subjected to erosion, and none give evidence of any appreciable concomitant tilting. They are all unconformities without dip. Places where the unconformity above the Saint Louis may be seen are not numerous, and nowhere does the base of the Coal Measures happen clearly to overlap the eroded ledges of the underlying Saint Louis. That the erosion interval was quite extensive is nevertheless evident from the fact that the latter formation in some places rests on the upper divisions and elsewhere on the lower divisions of the Saint Louis. Thus in sections 9 and 10, Liberty township, the Coal Measure shales rest on Pella marls and limestones, but under the bridge near the center of section 23 in the same township the underlying limestone is arenaceous and evidently belongs to the Verdi division. On Wolf creek and at some places on Brush creek the Pella beds also appear, but on Cedar and Walnut creeks the Coal Measures are again often found resting on the Verdi, and the Pella beds are absent. On Cedar creek, in Round Prairie township, the upper formation rests on the lower at levels both above and below the Pella beds, and reliefs of forty or fifty feet on the surface of the Pella beds are evident. Sometimes the Coal Measure shales and sandstones extend down into cavern-like or ditch-like excavations in the surface of the limestone. Such instances have been described in sections 9 and 10, in Liberty township, and were noted in some of the sections on Turkey creek. A doubtful case of unconformity has been mentioned under the heading "Chester Shales?" It occurs above a green shale lying below the base of the undoubted Coal Measures, in Cedar and Round Prairie townships on Cedar creek, as already set forth. During the Mesozoic and the Tertiary ages the land was again subjected to erosion, which was most extensive and protracted, and this period is recorded in the unconformity between the Paleozoic rocks and the drift, which is everywhere in evidence. The drift may rest on any of the members of the older rocks at elevations varying at least a hundred feet. But even here no great general tilting is apparent. Even this unconformity is, in the main, an unconformity without dip.

Glacial Scorings.— Some obscure glacial scorings were seen on the south bank of the middle fork of Walnut creek northeast of

Perlee. They were made on the surface of a broken ledge of the Saint Louis limestone and were covered by calcareous yellow till, only the edge of the ledge being exposed. There were two sets of scorings, one trending S. 75° W. and the other S. 35° E., as near as could be made out. The exact locality is immediately to the west of a ford across the stream in a private road about twenty rods west of the old Chicago, Rock Island and Pacific railroad bridge and about thirty rods east of the west line of section 23 in Penn township.

ECONOMIC PRODUCTS.

Building Stone.

Although there are considerable quantities of building stone no extensive quarries have yet been opened. This is probably due to the fact that the best rock is not found in the most accessible places, and perhaps also to the quite general distribution of accessible ledges yielding fairly good stone, in almost every township. This latter circumstance has to some extent prevented centralization of the industry. At some time or other rock has been quarried at probably not less than half a hundred different places, but not one quarry is now worked the year round, or even continuously during one season. The Pella beds contain several ledges, which yield dimension stone and material for bridge work. Extensive quarries might be opened and worked at several points along Cedar creek in Round Prairie and Cedar township. Soft and easily worked sandstone might be quarried at no great distance from the new line of the Chicago, Burlington and Quincy railroad east of Krum. The sandstones of the Coal Measures in Liberty and Cedar townships might in many places yield large, strong and durable blocks and slabs, such as may be seen at the old Lamson residence on Cedar creek bluff, southwest of Fairfield.

It may not be amiss to here correct a misuse of the name "granite" which seems common among some quarrymen in the west part of the county who take out "granite" from the ledges of the Coal Measures in that region. The rock which is here generally known by that name is a fair quality of sandstone, in which the sand is cemented together by

a copious calcareous matrix. It is a strong rock, except in places where it has been subjected to weathering. But the application to it of such a name, which is entirely erroneous, might easily occasion distrust among competent workmen and thus prevent or delay its general introduction, even for purposes to which it is well adapted.

Clay.

Only two firms are engaged in the manufacture of brick and tile. Rainy Brothers operate a drain-tile and brick factory immediately west of the city of Fairfield. It is located on the south side of the Chicago, Burlington & Quincy railroad, just west of the city. The value of the plant is estimated at $15,000. Some nineteen men are employed, and last year the company made and sold about 700,000 brick and 800,000 tile, the former retailing at $7.50 and the latter at from $10.00 to $60.00 per thousand, according to size. The tile is usually dark in color. It is strong, durable and uniformly well burnt. Considerable quantities of a twelve inch tile without rim are made, and this has

FIG. 68. Rainy Brothers' brick and tile factory, Fairfield.

been used for sewers in Fairfield. Two kinds of clays are used. The clay pit near the plant contains loess above and a leached gumbo below. Both the loess and the gumbo are entirely free

from lime. With this is mixed a weathered Coal Measure clay in proportions varying from one-third to one-half of the whole. Each is first ground or thoroughly crushed and then the two ingredients are mixed in a pug mill. The Coal Measure clay contains a large amount of fire clay and is hauled a distance of a mile and a half. Drying is by steam, and all burning is done in five down draft kilns. Most of the tile is exported to the west part of the state, to Chariton, Creston, Shenandoah, Milo and Dallas Center. Most of the brick is consumed by the home market, but some has been shipped for sidewalks to outside places, notably to Lenox and Kent. The Keb coal, from near Ottumwa, is exclusively used in the kilns.

Downey & Mitchell operate a brick and tile factory at Packwood. About 150,000 brick and as many tile are made in a year. Five men are usually employed. A twelve horse power engine runs a soft mud machine. The product is all dried in a shed and burnt in two down draft kilns. Brick brings $8.00 per thousand and four inch tile $13.00. Nearly all the tile made is of this size. Most of it is sold in the home market, and the rest is freighted to the nearest stations. The clay used is a leached and weathered upland loess.

In conclusion it may be said that this county has an abundance of well weathered clays at a number of localities, suitable for the manufacture of brick and tile.

Coal.

A detailed account has already been given of the distribution and character of the Coal Measures, and it is hardly necessary to say much here on the economic side of the same subject. The Jefferson County Coal Company, operated some mines at Perlee from 1870 to 1884. About 100 acres of coal were taken out. They supplied the Chicago, Rock Island & Pacific Railroad company with an average of about eighty tons a day for fourteen years. The Washington Coal Company also operated quite extensively for several years at the same place. Still earlier considerable quantities of coal were for many years shipped from the mines northwest of Lockridge. At present only one mine ships coal and its annual output does not exceed 3,000 tons. This is the

W. C. Smith Coal Company, near Lockridge. The decline in price of coal is regarded as the chief cause of the late decline in the industry. Small mines, or "banks," are worked, usually only in the winter, at a number of places, as may be seen from the statistical table below. Occasional mining or quarrying of coal is also done by the farmers. It is safe to say that coal has at one time or another been taken out at half a hundred different places throughout the county.

A glance at the geological map shows that this region is on the edge of the Coal Measures. To the north they have been carried away by erosion. Even in the south part of the county they have frequently been cut through by the streams. Probably there are places on the uplands where they are absent under the drift in the south and in the middle tiers of townships. It has been shown that the contained coal seams are very changeable, thinning out and disappearing in short distances. At times there is no coal in the shales and sandstones which remain. This unreliable character of the seams has interfered with extensive mining, and no doubt always will.

On the other hand, it cannot be doubted that many times more workable coal yet remains than has been taken out. An examination of the location of the mines will show that they have invariably been located on outcrops along the streams, or in the vicinity of such places. Not one mine has been located by prospecting on the uplands away from the streams. Evidently such localities have suffered least from erosion and the best chances for coal ought to be there. But such prospecting will always be expensive. It must be thorough and it should be done by competent and reliable men. No one should undertake it without sufficient means. The writer believes that workable seams of coal may be found by prospecting on the uplands, especially in Des Moines, Liberty and Locust Grove, and probably also in Penn, Buchanan, Fairfield, Cedar, Round Prairie and Lockridge townships.

STATISTICAL TABLE OF COAL MINING IN JEFFERSON COUNTY.

OPERATOR'S NAME.	LOCATION OF MINE BY TOWNSHIP AND SECTION.	NATURE OF MINE.	REPORTED THICKNESS OF VEIN	ANNUAL OUTPUT IN BUSHELS	NUMBER OF MEN EMPLOYED	PRICE PER BUSHEL IN CENTS.	MARKET.
W. C. Smith Coal Co	Lockridge, Sec. 27	Shaft	4.5	100,000	10	8	Mt. Pleasant, New London, home
Green & Looney	Penn, Sec 27	Shaft					Home
Sheckleton Heirs	Penn, Sec 27	Shaft					Home
Bowen & Wilcox	Liberty, Sec. 23	Slope	4				Fairfield, home.
Albert Gardner	Liberty, Sec 15	Shaft	3	17,000	4	7	Home Fairfield.
D. W Bates	Liberty, Sec 24	Shaft	3 to 5	15,000	4	8	Home.
A J. Zimmerman	Liberty, Sec. 30	Drift	4	30,000	5		Home.
C. F. Faulkner	Fairfield, Sec 27	Shaft		10,000			Fairfield.
Wm Gonterman	Des Moines, Sec 20	Shaft	4	?			Home
James Gonterman	Des Moines Sec. 29	Slope	4				Home.
Caves Brothers	Des Moines, Sec. 30	Shaft	2		3		Home
Frank Cloke	Des Moines, Sec 3	Drift	3		2		Home

Water Resources.

The general level of the ground water has steadily and gradually sunk throughout this region since it has come under cultivation. The change ranges from five to thirty feet. In the city of Fairfield shallow wells must now be made from ten to fifteen feet deeper than in the early days of the settlement to secure water. Near the broken tracts following the streams shallow wells have begun to fail entirely and farmers are now beginning to drill deep wells drawing water from the bed rock. To insure a good and constant supply, such wells should go through the Coal Measures and into the Saint Louis, except in places where the former consist largely of sand rock. Owing to the variability in the development of the Coal Measure strata, deep wells in this county must also necessarily vary and no general rule can be laid down for well makers here. This is shown by past experience, and uncertainty of results is one of the reasons why, as yet, comparatively few deep wells have been made. The uplands on the divides in Polk and Black Hawk townships constitute an exceptional region. Here the underground drainage is almost stagnant and the water lingers on the surface of the Kansan till at the base of the loess and there is yet a constant supply which can be reached at depths varying from fifteen to twenty-five feet.

The water-works at Fairfield were built in 1884. They consist of a standpipe eighty feet high and twelve feet in diameter and a pumping station with two fifty horse power engines. The level of the base of the standpipe is thirteen feet below the level of the public square. Two deep wells were used for a short time at first, but proved unsatisfactory. Two reservoirs were then constructed, which are supplied with a sufficient supply of surface drainage from a natural basin (park) located north of the city. The city has four and a half miles of water mains with forty hydrants and 400 taps. In 1900 thirty-eight million gallons were pumped.

Soils.

The soil is mostly loess. On the flat uplands the black mould is from two to four feet deep. On a divide east of Fairfield it has been rich enough in carbonaceous material to be used for the

making of railroad ballast. On the slopes the soil consists of weathered bowlder clay with a superficial admixture of loess. In such places it contains a few small pebbles. On the high terraces along Cedar creek there is a greater admixture of fine clayey material and the soil is more adherent and more retentive of moisture. In dry seasons it becomes quite hard. The soil on the bottom land is invariably a rich black loam. The only place in the county where there is a more open and sandy soil is on the south bluffs of the Cedar in sections 4, 5 and 6, in Liberty township. In this vicinity some of the farmers have engaged in the raising of small fruit and garden truck. The thorough leaching of the ground in this county has left a small amount of carbonate of lime near the surface as compared with some other parts of the state, and it is probable that an artificial supply of this mineral might improve the soil in some places on the flat uplands.

ACKNOWLEDGMENTS.

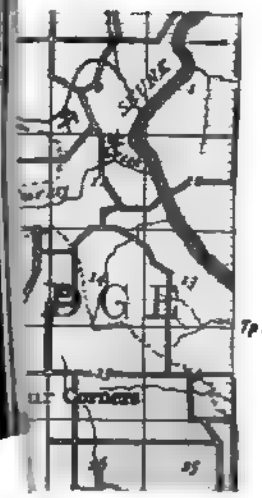
In the work on this county the author has received valuable aid from Professor S. Calvin, the director of the Survey; from A. G. Leonard, Assistant State Geologist; from Dr. Schuchert, of the Smithsonian Institution; from Dr. Eastman, of the Harvard Museum, and from Dr. Sardeson, of the University of Minnesota.

BY

J.A. UDDEN
1902.

Scale

1 ½ 0 1 2 3 4 5 Miles



BY

J.A.UDDEN
1902.

Scale

1 ½ 0 1 2 3 4 5 Miles

5 Kilometers

GEOLOGY OF WAPELLO COUNTY

BY

A. G. LEONARD.

GEOLOGY OF WAPELLO COUNTY.

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CONTENTS.

INTRODUCTION.

LOCATION AND AREA.

Wapello county forms one of the second tier of counties north of the Missouri line and is fourth in order of succession from the Mississippi river. It is thus situated well toward the southeastern part of the state. Its northern boundary is formed by Mahaska and Keokuk counties. Jefferson borders it on the east, Davis on the south and Monroe on the west.

Included within these boundaries are twelve congressional townships with a total area of 432 square miles. The Des Moines river crosses the county diagonally from northwest to southeast.

Wapello is one of the leading coal counties of the state and in 1901 it ranked seventh in the production of that mineral. It also holds an important place as a producer of clay products and stone. The importance of the mineral resources of the county is shown by the fact that in 1901 the total value of its coal, clay and stone amounted to $404,503.

PREVIOUS GEOLOGICAL WORK.

The first geologist to visit this region was D. D. Owen, who in the summer of 1849 made a trip up the Des Moines as far as Fort Dodge. In his report* he mentions the heavy beds of Coal Measure sandstone occurring along the river between Eldon and Ottumwa and the ledges of limestone outcropping at and above the latter town. Several beds of coal were noted on Sugar creek and along the river below the mouth of that stream.

In 1856 A. H. Worthen made an examination of the valley of the Des Moines and gives in his report several sections occurring along that river in Wapello county.† During the following year the same geologist again visited the region and published a brief general account of the geology of the county.‡ At that time the principal coal banks were in the neighborhood of Dahlonega and Kirkville, and in the river bluffs, four miles be-

* Geol. Surv. of Wis., Iowa and Minn., pp. 113-114, Philadelphia, 1852.
† Geol. of Iowa, Vol. I, pt. i, pp. 162-166. 1858.
‡ Geol. of Iowa, Vol. I, pt. i, pp. 248-258, 1858.

low Eddyville. In 1867 C. A. White visited the coal mines which were then in operation in the county and in his report* gives their location, together with the thickness and number of veins.

The record of one of the artesian wells put down at Ottumwa was published in 1889 by C. H. Gordon† and the record of this and another well is given and discussed by W. H. Norton in his report on the Artesian Wells of Iowa‡ In 1893 the coal mines of the district were visited by members of the present Survey and a brief account of them is contained in the report on the Coal Deposits of Iowa, by C. R. Keyes §

From the above it will be seen that little work had been done on the geology of Wapello county except that of a fragmentary and very general nature, which was all it was possible to do in the time which had been devoted to the study of the area.

PHYSIOGRAPHY.

TOPOGRAPHY.

The topography of this region is due entirely to erosion and the valleys and ridges have been formed by the action of running water on the soft drift materials and the underlying indurated rocks. The region was once a level or nearly level drift plain, from which the inequalities of the present surface have been carved by the streams. The greater portion of this plain has been thoroughly dissected and deep valleys eroded in it. In the northeastern part of the county the surface has been much less affected by erosion than the rest of the area, the land is gently rolling and the creeks have cut comparatively shallow valleys. In strong contrast with this are the southwestern townships and those crossed by the Des Moines river. In these the surface has been deeply cut by valleys which branch and rebranch in all directions and produce a rough and rugged topography. But all the divides are seen to rise to the same height, and if the valleys were filled up to the same level the original plain would be restored. This thoroughly and deeply dissected area includes

* Second Ann. Rep. of State Geologist, pp. 108-112, 1868.
Geol. of Iowa, Vol II, pp 261-270 Des Moines, 1870.
† Am Geol., Vol. IV, pp 237-239, 1889.
‡ Iowa Geol. Surv., Vol VI, pp. 317-320, Des Moines, 1896.
§ Iowa Geol. Surv., Vol. II, pp. 383-393, Des Moines, 1894.

Green, Keokuk and Polk townships, with parts of Adams, Center, Cass, Columbia and Richland. The upland plain includes Highland, Competine and Pleasant townships, together with parts of Dahlonega, Agency and Washington townships. A northwest-southeast line passing through Kirkville, Dahlonega, Agency City and Ashland would separate this rolling plain from the deeply eroded and rough country bordering the Des Moines river and lying south and west of it.

The most marked topographic feature of the region is the broad valley of the Des Moines. That stream crosses the county diagonally from northwest to southeast and has cut its broad valley to a depth of from 150 to 200 feet. The flood plain varies in width from one-half to two miles, the average being about one mile. From Eddyville to Ottumwa the valley is noticeably narrower than it is below the latter town. Above Ottumwa the average width is less than three-quarters of a mile, while from Ottumwa to Eldon it is one and one-quarter miles. A large part of Ottumwa is built on the broad bottom land of the Des Moines, whose valley here broadens out until just below the town it has a width of two miles.

This difference in the width of the valley is probably due to a

FIG. 64. The broad valley of the Des Moines, two and one-half miles below Cliffland station; looking southwest across the flood plain, which is here one and a half miles wide.

difference in the rock in which it has been carved. Below Eddyville as far as the county seat the river has cut its channel through the soft Coal Measure shales and into the harder and more resistant Saint Louis limestone. Below Ottumwa the limestone lies beneath the bed of the river and the stream, in forming its valley, has had to erode only the easily washed shales and soft sandstones. The recession of the sides by lateral cutting of the river and by atmospheric agencies would progress rapidly in these readily affected materials. On the other hand, where the channel is in limestone, the widening process goes on less rapidly owing to the greater resistance offered by the latter rock.

In the broader portion of its valley between Ottumwa and Eldon the Des Moines meanders back and forth across its flood plain, striking first one bluff and then the other. At the former place the river makes several broad loops and its course has changed in recent times, as is shown by an old abandoned channel. Another excellent example of stream meanders is furnished by Soap creek as it flows across the flood plain of the Des Moines river, in the southeastern corner of the county.

The behavior of Village creek when it enters the valley of the Des Moines, in section 8 of Keokuk township, is so peculiar as to deserve notice. As soon as the flood plain of the latter stream is reached, instead of keeping on in the same direction as before, it turns abruptly and, taking a course at right angles to its former one, it follows along close to the side of the valley and enters the river a mile or more below. The cause of the creek taking this course and following the bluff is probably found in the slight outward slope of the flood plain. It is well known that there is a tendency for a flood plain to be highest next the river, where the deposition of silt goes on most rapidly, and from this point it slopes gently toward the sides of the valley. On this account when a tributary stream enters a valley it may be compelled to follow down along one side, where the land is lowest, until a favorable opportunity is afforded for joining the larger stream. In the present instance this is when the river makes a bend and comes over to its west bluff. North Avery creek at one time followed the edge of the flood plain in the same way as Village creek and entered the Des Moines at Chillicothe, one

mile below its present mouth. The old channel still remains and is occupied by the river during ordinary stages of the water. The formation of a new mouth and the abandonment of its old channel were caused by lateral cutting. At the bend where the creek abruptly changed its course the current was swiftest on the outer side, the cutting of the bank was most rapid at that point and the creek thus gradually shifted its channel until it entered the main stream by its present mouth. On the map of the county made six or seven years ago, North Avery is represented as emptying into the river by way of its old channel and its new mouth has probably been formed within a few years.

The Des Moines and its tributaries have eroded their valleys through the drift and have cut down deep into the Coal Measure strata, while in the northwestern part of the county they have worn their channels into the underlying Saint Louis limestone. At Ottumwa, where the Des Moines flows over the ledges of this limestone, the Coal Measures rise from 100 to 150 feet above the river and at Eldon to a height of 135 feet above the same stream.

The chief drainage lines of the county appear to be preglacial. The valleys of the Des Moines and its larger tributaries were probably formed, at least in part, before the advent of the ice sheet. During glacial times they were filled with drift and the entire region was covered with a mantle of that material which obliterated the topographic features previously existing. Upon the retreat of the ice a nearly level drift plain was left where before there had been a surface deeply cut by the stream into valleys and ridges. But in the old preglacial valleys where the drift was thickest it would settle more than upon the uplands over which it was thinner. Slight depressions would thus come to occupy the place of the former valleys and these sags would be taken possession of by the streams which established themselves on the surface upon the withdrawal of the ice. These streams would quite readily carry away the loose materials of the drift until they had cut their way down to the bed rock, clearing out and deepening the former waterways.

That the valleys are preglacial is shown by the fact that in places the drift is seen to follow down the sides, covering up the strata which once formed the walls. This is what would be ex-

pected if the valleys were already formed when the mantle of drift was laid down.

The following table gives the elevations above tide of the principal towns of the county and several just outside the area. The figures are taken from Gannett's Dictionary of Altitudes in the United States:

LOCALITIES.	ELEVATION.
Agency	807
Batavia	727
Bidwell	720
Blakesburg	913
Chillicothe	660
Dudley	674
Eddyville	676
Eldon	630
Hedrick	827
Highland	780
Ottumwa	650

Batavia is just over the east line of the county and Hedrick is a mile from the north line. Agency, Blakesburg, Hedrick and Highland are located on the upland plain, while the other towns are located in the valleys. The highest part of the area is in Adams township, in the vicinity of Blakesburg, and the lowest point is in the Des Moines valley at Eldon.

DRAINAGE.

The drainage of Wapello county has reached its maturity. The streams, with their numerous tributaries, reach out to all parts of the land and carry off the water as rapidly as it falls upon the surface. The Des Moines and its tributaries drain about two-thirds of the area, and the affluents of the Skunk river, Competine and Cedar creeks, with their branches, drain the other third. The former drainage system, as already stated, has cut valleys which are much deeper than those formed by the latter system. The major stream and its chief tributaries flow in valleys from 150 to 200 feet in depth, while Competine and Cedar creeks, which drain the northeastern townships, have valleys with a depth of not more than forty to sixty feet. They are broad, with gently sloping sides, and in no place do they extend through the drift to the underlying Coal Measures. Though the drainage

lines of the northeastern townships ramify over the surface until they reach all portions of the area, the channels are shallow and the land is not deeply dissected as in other portions of the county. The reason the tributaries of the Skunk river have not eroded their valleys to the same depth as those of the Des Moines system is found in the fact that the former streams flow long distances before entering the Skunk river, and the latter in turn enters the Mississippi over thirty-five miles above the mouth of the Des Moines. Cedar and Competine creeks, therefore, have much less of a fall and erode their channels more slowly than the Des Moines drainage system. The Des Moines, being a large stream, has been able to cut its valley at a comparatively rapid rate and its tributaries have carved their valleys down to the same base level.

The chief tributaries of the Des Moines river are North Avery, South Avery, Bear, Village and Soap creeks, all of which enter it from the west or southwest. The streams flowing in from the north are smaller, the majority of them being only a few miles in length. They have narrow, steep-sided valleys and their courses are approximately at right angles to the major stream.

In traversing the county from the northwest corner to the opposite one, a distance of twenty-eight miles, the Des Moines has a fall of forty-eight feet. But the gradient below Ottumwa is twice as great as it is above. From Eddyville to Ottumwa the river has a fall of one and one-eighth feet to the mile, but from the latter town to Eldon the fall is two and one half feet to the mile.

STRATIGRAPHY.

The geological formations which are present in Wapello county are few in number, but of much importance economically. They belong to the Carboniferous and Pleistocene systems. The oldest strata which appear at the surface are the limestones of the Lower Carboniferous. Overlying these, but separated from them by an unconformity representing a long time interval, are the more recent shales and sandstones of the Upper Carboniferous. It is when these upper beds, which once covered the entire county, have been cut through by the larger streams that the Lower Carboniferous limestones are exposed. As will be seen

by a reference to the map, they are found in the valley of the Des Moines and along some of its chief tributaries.

Overlying these indurated rocks, which are of marine origin, is a formation of entirely different character and of very much younger age. It is made up of the loose and heterogenous deposits of the Pleistocene, including the drift and loess. These were formed at the time the great ice sheets from the north invaded Iowa and left behind the mixture of clay, sand, gravel and bowlders which forms the drift. The drift is covered by a thin layer of silt-like material, the loess. Belonging to the same period is the alluvium of the river valleys, formed by the streams during periods of overflow. The taxonomic relations of these formations are shown in the following table:

SYNOPTIC TABLE OF THE GEOLOGICAL FORMATIONS OF WAPELLO COUNTY.

GROUP.	SYSTEM.	SERIES.	STAGE.	SUB STAGE.
Cenozoic.	Pleistocene.	Recent.	Alluvial deposits.	
		Glacial.	Loess.	
			Kansan drift.	
Paleozoic.	Carboniferous.	Upper Carboniferous or Pennsylvanian.	Des Moines (Coal Measures)	
		Lower Carboniferous or Mississippian.	Saint Louis.	Pella.
				Verdi.

The Deeper Strata.—Our knowledge of the deep strata of the region is gained from the deep wells sunk at Ottumwa in search of water. The record of the well of the Artesian Well Company, as given in W. H. Norton's report on the Artesian Wells of Iowa,* is as follows:

* Iowa Geol. Surv., Vol. VI, p. 319, Des Moines, 1896

		THICKNESS.	DEPTH.	A. T.
18.	Loam. Pleistocene	21	21	†639
17.	Limestone, Mississippian	21	42	608
16.	Shale, Mississippian	14	56	594
15.	Sandstone, Mississippian	30	86	564
14.	Limestone, Mississippian	60	146	504
13.	Shale, Mississippian	20	165	484
12.	Sandstone, flinty, Mississippian	40	206	444
11.	Sandstone, Mississippian	30	236	414
10.	Limestone, Mississippian	195	431	219
9.	Shale, Mississippian Kinderhook	160	591	59
8.	Limestone	200	791	-141
7.	Limestone	180	971	-321
6.	Limestone mixed with sand, Devonian, Silurian and Ordovician	96	1,067	-417
5.	Sandstone, white, Saint Peter	110	1,177	-527
4.	Shale and limestone, Oneota	200	1,377	-727
3.	Slate, Oneota	19	1,396	-746
2.	Limestone, Oneota	320	1,715	-1,065
1.	Limestone, water bearing Oneota	332	2,047	-1,397

† Approximately.

No Upper Carboniferous strata were passed through in this well since it was sunk in the Des Moines valley where those beds have been removed by erosion. No. 17 is the upper portion of the Saint Louis formation, which everywhere in the county underlies the shales and sandstones of the Upper Carboniferous series. It is seen outcropping in the bed of the river at Ottumwa.

The Carboniferous System.

SAINT LOUIS STAGE.

The rocks belonging to this stage are the oldest which appear at the surface in Wapello county. They consist of limestones, marly shales and sandstones. The limestone, which is quite uniform in character and appearance, is very compact, fine-grained and light gray or blue in color. It frequently contains small particles or crystals of iron pyrites and careful examination will usually show minute fragments of fossils, especially on a weathered surface. Some of the rock, however, resembles lithographic stone in appearance and bears no evidence of organic remains. The beds vary in thickness from two or three inches to two feet. Interstratified with the limestones are gray, marly shales which are commonly quite rich in fossils. These marls, on long con-

tinued exposure to the weather, become soft and earthy, and wearing away more rapidly than the limestone, leave the latter in projecting ledges. The marly layers often attain a thickness of two or three feet and range from that down to an inch or less. They are very characteristic of the upper portion of the Saint Louis. At several points sandstone was observed underlying the calcareous beds, and these arenaceous deposits are also reported from a number of wells in different parts of the county. Where seen in its outcrops the sandstone is soft and white or yellow in color.

Where studied in adjoining regions it has been found possible to divide the Saint Louis into three members. The Springvale beds, which form the lowest of these divisions, are not exposed anywhere in the county. They are composed of magnesian limestones, marly shales and some sandstone. The Verdi beds constitute the middle member and are made up of alternating layers of limestone and sandstone. The latter rock occasionally reaches considerable thickness, and in southeastern Mahaska county single beds are found twenty-five to thirty feet thick.* The limestones are sometimes hard and very compact, sometimes brecciated. This middle member also is but poorly represented in Wapello county, but the soft sandstone which is found beneath the limestone and marls is believed to belong to the Verdi beds.

The upper division of the Saint Louis is the Pella beds, and the limestones and marls described above belong to this member. It is this portion which furnishes the excellent building stone quarried at many points in this and neighboring counties. The Pella beds, and especially the marly layers, are rich in fossils, the following being some of the more common:

Zaphrentis pallaensis, Worthen.
Productus ovatus, Hall.
Athyris (*Seminula*) *subquadrata,* Hall.
Allorisma marionensis, White.
Spirifer keokuk, Hall.
Orthothetes, has been described as *Orthis keokuk.*
Pugnax ottumwa, White.
Astartella sp?
Bellerophon sp?

* Bain; Iowa Geol. Surv., Vol. V, p. 150, Des Moines, 1896.

The thickness of this upper division is from fifteen to twenty feet.

The Saint Louis limestone is confined to the northwestern part of the county, where it outcrops in the valleys of the streams which have cut their channels through the overlying Coal Measure shales and sandstones and exposed the beds beneath. Though the strata of the formation underlie the entire area, as shown by deep wells, they are in most places buried beneath the deposits of the Upper Carboniferous. It will be seen from the map accompanying this report that the limestones occur in the valley of the Des Moines from Ottumwa to Eddyville, and also south of Eldon, just north of the Davis county line, along the South Avery and North Avery creeks and along the lower courses of many of the smaller streams entering the river from the north and west. The Saint Louis also probably occurs beneath the drift in several sections in the northern part of Competine and Highland townships, as shown from outcrops across the line in Keokuk county.

The rock is extensively quarried at Dudley, Ottumwa, and Eddyville.

The character of the upper portion of the Saint Louis formation is well shown in the following sections.

I. SECTION IN THE CAWLEY QUARRY, ONE MILE SOUTH OF EDDYVILLE, IN NW. ¼ OF SEC. 7, TP. 73 N., R. 15 W.

		FEET.
5.	Drift	3
4.	Residual clay, deep red	1
3.	Limestone, thin bedded	1
2.	Limestone, compact, light blue or gray, in ledges 6 to 15 inches thick; marly partings between some of the ledges. In places the limestone contains nodules of limonite	8
1.	Unexposed to river	37

The limestone here rises about fifty feet above the Des Moines river. A short distance south of here in another quarry on Miller creek the following section is shown:

II. MILLER CREEK SECTION.

		Feet.
6.	Drift	3
5.	Residual clay	1
4.	Limestone in thin beds	1
3.	Marly shales with 6 inch band of limestone	3
2.	Limestone in distinct layers separated by marly partings	8
1.	Unexposed to creek	25

About one-quarter of a mile below the mouth of Miller creek several feet of black, fissile, Coal Measure shales appear overlying the limestone, and one and a half mile above the same point in Monroe county there is a four and a half foot seam of coal twenty feet above the Saint Louis, separated from it by shale and fire clay. Eight to ten feet of this black shale outcrop at the wagon bridge in the Ne. ¼ of Sec. 18, Columbia township. The limestone appears along Palestine creek, five feet of it being exposed below the bridge in section 21 of the same township.

Sections on North Avery Creek. The Saint Louis limestone is exposed at many points along North Avery Creek between Chillicothe and Dudley. In the southwest quarter of section 26 the following section is shown:

III.

		Feet.
7.	Drift, with ferruginous gravel at base	6 to 15
6.	Sandstone	2
5.	Shale, gray, sandy	8
4.	Sandstone	2
3.	Shale, sandy	3
2.	Limestone, thin bedded below	5
1.	Unexposed to creek	6

The limestone (No. 2) is oolitic in part. Nos. 3 to 6 probably belong to the Upper Carboniferous (Coal Measures). The following section is exposed in the old railroad quarry, just west of the station at Dudley:

IV.

		Feet.
6.	Drift	10
5.	Limestone	1
4.	Marly shale, gray	2
3.	Limestone	½
2.	Marly shale, gray	1
1.	Limestone, light gray, very compact	4

One-half mile east of Dudley the Chicago, Burlington & Quincy railroad has opened a new channel for the North Avery creek in order to straighten out its course. In this artificial cut the Saint Louis limestone is well exposed and the following strata appear at the west end of the opening:

V.

		FEET.
7.	Drift	10
6.	Limestone	2
5.	Marly shales, gray	2
4.	Limestone	½
3.	Marly shales, gray	3
2.	Limestone, very fine-grained, compact, light gray, thin-bedded above	10
1.	Sandstone, soft, exposed in bottom of cut	1

The ledges of No. 2 are the quarry beds which are worked so extensively at Dudley and elsewhere. The sandstone (No. 1) probably belongs to the Verdi beds, the rest of the section to

FIG. 65. Monoclinal fold in the Saint Louis limestone, one-half mile east of Dudley.

the Pella. As these strata are followed toward the east they are carried up by a gentle monoclinal fold with a dip of 20° At the east end of the cut they are overlain by Coal Measure strata. From six to eight feet of the limestone beds exposed at the west end of the cut have been eroded and are replaced by black shale. The section is as follows:

VI.

		FEET.
4.	Drift	10
3.	Shale, black, fissile, contains much pyrites	3
2.	Limestone, much decomposed and covered with iron oxide (limonite)	2 to 3
1.	Sandstone, soft, white on inside, stained brown on outer surface, exposed	4 to 6

The above is of especial interest since it shows the unconformable contact between the Upper and Lower Carboniferous or between the Saint Louis and Coal Measure strata. The lime-

FIG. 66. Contact between the Saint Louis limestone and Coal Measure shales. The limestone ledges of the Pella division overhang the Verdi sandstone, and are overlain by black shales.

stone and sandstone are both stained brown by limonite, formed by the decomposition of the original iron pyrites, and are much decomposed and rotted. The limestone has been dissolved in many places and is badly pitted. The underlying sandstone, being soft, has been worn away by the water of the creek, leaving the limestone ledges overhanging. An effective agent in the decomposition of the limestone has been the sulphuric acid derived from the iron pyrites of the shales. The Saint Louis outcrops at many points along South Avery creek, and below the limestone of the Pella beds the sandstone of the Verdi beds often appears. At the sharp bend of the creek to the south, in the Sw. ¼ of the Se. ¼ of Sec. 35, Tp. 73 N., R. XV. W., twenty feet of limestone strata are exposed and have been quite extensively quarried. Only a short distance south of here a soft, yellow, micaceous sandstone (Verdi) appears beneath the calcareous beds. In the Ne. ¼ of Sec. 10, Polk township, the contact between the Saint Louis and Coal Measures is again seen. Overlying the limestone is a very irregularly bedded, light gray, soft sandstone which contains streaks of coal. Below the sandstone at one end of the outcrop

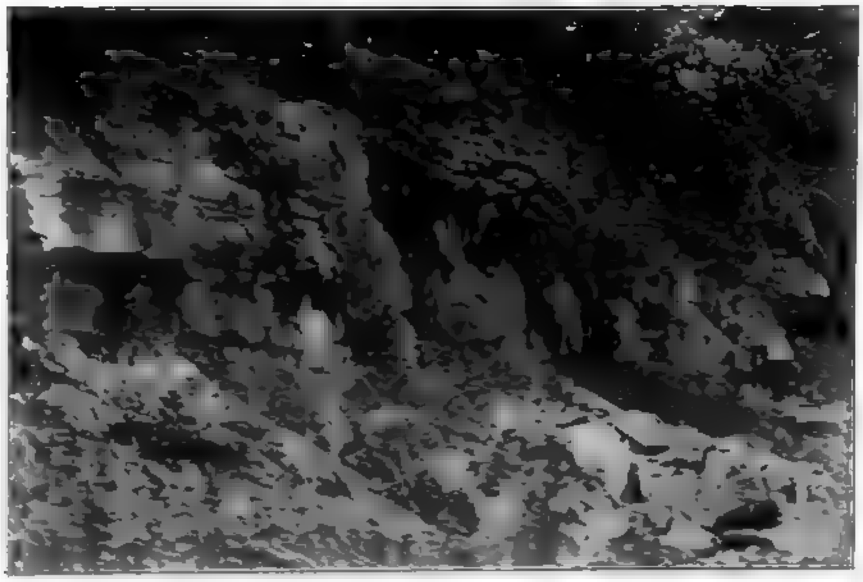

Fig. 6[illegible]. Unconformity between the Saint Louis limestone, 1, and the Coal Measure shales, 2. The shales rest on the uneven and weathered surface of the limestone. At the old quarry on the Des Moines river three miles above Ottumwa.

there is a black shale and some clay. The most southern exposure of the Saint Louis along South Avery occurs in the bed

FIG. 68. Contact between the Saint Louis limestone, 1, and Coal Measures, 2. Three miles above Ottumwa.

of the stream in the Ne. ¼ of Se. ¼ of Sec. 10, Polk township. Just below the Chicago, Burlington & Quincy railroad bridge over the Des Moines river there is an excellent exposure at the old stone quarry.

VII. DES MOINES RIVER SECTION, NW. ¼ OF SW. ¼ OF SEC. 9, TP. 72 N., R. 14 W.

		FEET.	INCHES.
11.	Drift	20	
10.	Shale, black	15	
9.	Sandstone, with many carbonized stems of plants, thin-bedded and shaly above	4 to 5	
8.	Coaly seam, composed of laminæ of coal separated by thin, sandy layers, and containing much iron pyrites in nodules		½ to 2
7.	Fire clay		2 to 8
6.	Limestone, argillaceous, greatly decomposed on upper surface and containing much limonite, the carbonate of lime having been		

		FEET.	INCHES.
	Continued	[illegible]	
5.	Marly shale, gray	2	
4.	Limestone		6
3.	Marly shale, gray	3	
2.	Limestone	2	
1.	Concealed to river	6	

This section, like the previous one, shows the contact between the Saint Louis and Coal Measures. Nos. 1 to 6 belong to the former and Nos. 7 to 10 to the latter. The upper surface of the limestone (No. 6) is uneven and undulating and is decomposed to a depth of from six inches to two feet. So much of the lime carbonate has been dissolved out that the residue is composed largely of limonite.

VIII. SECTION IN QUARRY ON ROCK RUN, SW. ¼ OF NW. ¼ OF SEC. 15, TP. 72 N., R. 14 W.

		FEET.
4.	Drift, sandy and gravely, contains much iron..	3
3.	Limestone	2
2.	Marly shale, gray	2
1.	Limestone, gray, compact, contains cubes of iron pyrites, thin-bedded above	8

IX. SECTION IN QUARRY ON BEAR CREEK, NE. ¼ OF SW. ¼, SEC. 23, TP. 72 N., R. 14 W.

		FEET.
6.	Soil	2
4.	Marly shale, gray	1½
5.	Limestone, in thin beds	1⅓
3.	Limestone, in two ledges separated by marly parting	1
2.	Marly shale, gray	3
1.	Limestone, light blue, very compact	7

The Saint Louis limestone is exposed along Harrow's branch, in the city of Ottumwa, and in the bed of the Des Moines river at the same place. The most southern point at which the limestone outcrops at the surface, with the exception of the small area in the bed of the river about one mile below Eldon, is on Sugar creek, near where it empties into the river.

X. SECTION ON SUGAR CREEK IN SW. ¼ OF SW ¼ OF SEC 28, TP. 72 N., R. 13 W.

		FEET.	INCHES.
5.	Alluvial clay	5	
4.	Limestone, argillaceous, thin bedded	3	
3.	Limestone ledge	½	
2.	Marly shale, gray	2	8
1.	Limestone, in two ledges, exposed to bed of creek	2½	

The Saint Louis strata appear along Fudge creek as far north as Se. ¼ of Ne. ¼ of section 14, Columbia township, where it is seen in the bed of the stream. It also appears two miles south of Kirkville, along the stream with the east-west course, near the center of Ne. ¼ of section 20, Richland township. At this point the beds rise eight to ten feet above the creek and are composed of gray, marly shales with limestone ledges six inches to one foot thick. Overlying the calcareous beds are gray and black shales and thin-bedded sandstone.

A comparison of the above sections shows that in several of them the succession of strata is the same, namely, there are three limestones separated by marly shales. The thickness of the beds is also quite uniform over a considerable area. Thus the sections at Dudley (IV and V), on the Des Moines river (VII), and on Bear creek (IX), correspond very closely and from them can be made the following general section of the upper beds of the Saint Louis.

		FEET.
5.	Limestone	1 to 6
4.	Marly shale	2
3.	Limestone	½ to 1
2.	Marly shale	3
1.	Limestone, exposed	5 to 10

This gives a maximum thickness of about twenty feet for the upper division of the Saint Louis. The Verdi beds are represented by the soft, micaceous sandstone seen below the limestone in the artificial cut east of Dudley and on South Avery creek.

DES MOINES STAGE (COAL MEASURES.)

The rocks of this stage in the order of their aggregate thickness are clay shales, sandstones, limestones and beds of coal. The shales, which make up the great bulk of the Coal Measure strata, are of two varieties. One is carbonaceous, fissile and black in

FIG. 60. Bluff of Coal Measure sandstone at Cliffland station, showing the massive character of the rock and the irregular way it weathers.

color; the other is argillaceous, is not so fissile and is found in a variety of colors, of which gray predominates. By an increase in the carbonaceous material the black shale passes into bony coal and so into true coal. The argillaceous variety frequently becomes sandy and with the increase of this constituent it graduates into sandy shales and sandstone.

A thick bed of massive sandstone occurs along the Des Moines river about two miles below Ottumwa, and for nearly six miles it forms the bluffs on either side of the valley. It is well exposed at Cliffland station, on the Chicago, Rock Island and Pacific railroad. In places it rises as a steep escarpment 100 feet above the river. This massive bed of compacted sand is known to have covered an area of some eighteen square miles and probably more. The Des Moines has cut its valley through it and has carried away a large part of the bed. Such thick Coal Measure sandstones are known to occur at other localities in southeastern Iowa. The well known Red Rock sandstone in northern Marion county is a mass of this kind with a maximum thickness of over 100 feet. It has a length of at least eleven miles and a width of three miles. Another occurrence is at Raven Cliff (Tp. 75 N., R. XVII W., sections 32 and 33) in southwestern Mahaska county. Here for a distance of two miles along an old channel of the Des Moines

river there is a sandstone which is nearly 137 feet thick. In Wapello county, as well as at the other localities, the sandstone occurs near the base of the Coal Measures and rests unconformably upon the shales. At no place in this county was it seen to lie directly on the Saint Louis limestone, being separated from the latter by thirty feet or more of argillaceous strata.

The sandstone is composed of irregular grains of quartz which are somewhat loosely cemented together. It contains considerable iron in the form of limonite, which is either scattered uniformly through the mass or is gathered in concretions or nodules. The rock is soft, micaceous and gray or yellow in color. One of the most noticeable characteristics of this sandstone is its cross-bedding. This structure, which is exhibited in great perfection, is seen in almost every outcrop and is very seldom absent. Another noticeable feature is the presence of large numbers of iron

FIG. 70. Escarpment of Coal Measure sandstone along the Des Moines river, three miles above Eldon.

concretions. These are especially well shown in the bluff at Cliffland where the rock is filled with them. They are scattered irregularly through the sandstone but are arranged with their longest diameters in a horizontal direction. Their length is usually two or three times greater than their thickness. Measured along

the greatest diameter they vary in size from an inch to more than a foot. They are composed of a hard crust of limonite from one-eighth to one-quarter of an inch thick, the interior being empty or filled with an ocherous material, or an impure limonite. The hard, ferruginous crust of these concretions often projects beyond the rest of the rock, since they weather less rapidly than the soft sandstone.

Besides the thick bed of massive sandstone just described there are other sandy strata only a few feet in thickness alternating with the shales.

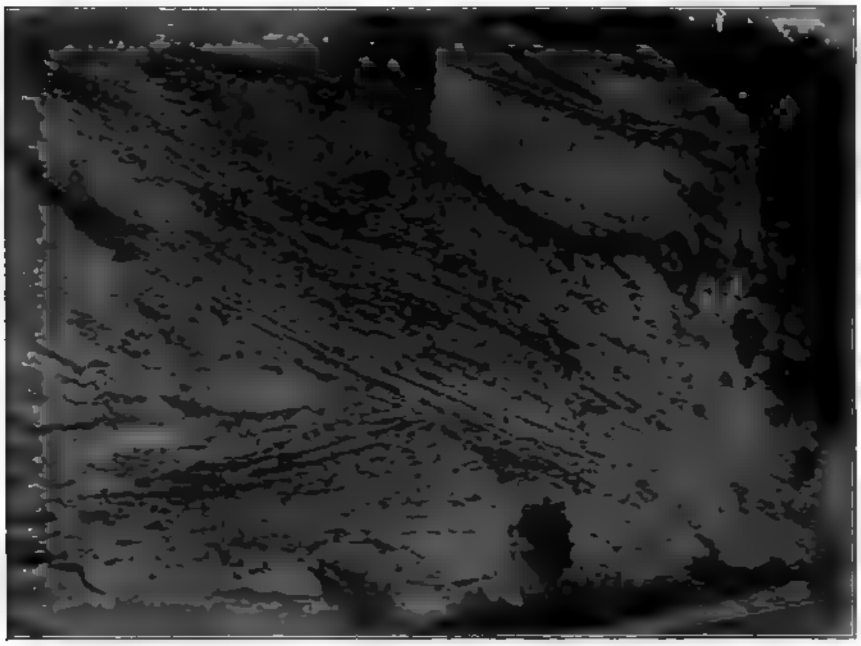

FIG. 71. Cross-bedding in Coal Measure sandstone, one-half mile below Cliffland station.

Occasional bands of limestone occur in the Coal Measures. One of these is seen in the bed of the river about one-half mile above the wagon bridge at Eldon. Near by, at the mouth of Big branch, two ledges of limestone appear, and others are seen along Sugar creek, less than a mile east of Ottumwa. The beds have a thickness of from eight inches to four feet. They are not continuous over large areas but thin out and disappear within a

short space. This rock is darker in color than that of the Saint Louis, is compact and usually very fossiliferous. In places it is concretionary and contains septaria, the cracks of which are

FIG. 72. Cross-bedding in the Coal Measure sandstone, along the Des Moines river, one-half mile below Cliffland station.

filled with calcite and sphalerite. The following fossils occur in these calcareous beds:

Productus muricatus, Norwood & Pratten.
Productus cora, d'Orbigny.
Productus punctatus, Martin.
Athyris (Seminula) subtilita, Hall.
Spirifer rockymountana, Marcou.
Nucula ventricosa, Hall.
Soleniscus brevis, White.
Orthonema conica, Meek & Worthen.
Loxonema, sp. ?

A brecciated limestone is also found in the Coal Measures of this area. It is seen in the northeast part of Ottumwa, 100 feet above the river. The ledge is two or three feet thick, dark gray

in color and composed of angular fragments from one quarter to one inch in length. Fragments of a similar rock were observed along Big branch, in Washington township, which had doubtless come from a ledge well up toward the top of the Coal Measures, though none of the limestone was here observed in place.

All the beds, whether they be shales, sandstones or limestone, are found to change rapidly when followed horizontally. No one of them is continuous over a very large area but they thin out and disappear and are replaced by other strata. Thus the shales which occur at one point will, within only a short distance, give way to sandstones or sandstone will pass into shales. The limestones likewise disappear and their place is taken by beds of different character. These lateral changes in the strata are often quite abrupt, the transition from one kind of rock to another being made within a small space. It is this changeableness of the beds which makes the correlation of the Coal Measure strata very difficult and often quite impossible. Two outcrops separated from each other by only a few yards or different parts of the same outcrop will frequently show marked differences in the succession, thickness and character of the beds. Examples of this are given under the description of typical sections. Not only do the inclosing strata vary rapidly but the coal seams themselves are not continuous for any great distance. They are more or less lenticular in shape, being thickest in the central portion and thinning out toward the edges.

As will be seen from the map, the strata of the Des Moines stage cover the entire county underneath the drift except where they have been cut through by the streams. Where the latter have eroded their valleys into and through the Coal Measures they have removed these younger beds and exposed the underlying Saint Louis limestone.

The thickness of the Coal Measures in Wapello county varies widely in different parts of the area. In a few places they are entirely absent, in others they are more than 200 feet thick. In the bluff at Ottumwa they are 150 to 175 feet thick, at Eldon they are about the same and in section 12 of Pleasant township they reach a thickness of 222 feet. It is probable that the maximum thickness of these strata in the county is not over 250 feet, and the average may be given as between 150 and 200 feet.

The following sections show the general character of the beds of the Des Moines stage.

I.—BEAR CREEK SECTION.

One of the best outcrops is on Bear creek, two miles west of Ottumwa, in Se. 1/4 of Ne. 1/4 of section 28, Center township.

		FEET.
15.	Drift	20
14.	Shale, argillaceous, gray, sandy in upper part.	20
13.	Shale, black, carbonaceous, fissile	3
12	Sandstone	3
11.	Shale, gray, argillaceous	2
10.	Shale, black, fissile, carbonaceous	5
9.	Coal, impure and bony, contains iron pyrites..	1/2
8.	Fire clay, filled with plant remains	1
7.	Shale, gray, argillaceous	5
6.	Shale, black	6
5.	Sandstone	1/3
4.	Shale, black	4
3.	Coal, bony and impure	1 1/3
2.	Shale, black, carbonaceous, fissile, rich in plant remains	1/2
1.	Shale, gray, argillaceous, exposed to creek....	20

It is probable that No. 3 is the same coal seam that is mined one mile and three-quarters northwest of here, on the opposite side of the creek. The vein there has a thickness of four and one-half feet and lies twenty-five feet above the Saint Louis limestone, as determined by test borings. The base of the above section cannot be far from the limestone, for the latter outcrops along the creek less than two miles below and rises fourteen feet above the stream.

II.—SECTION IN CLAY PIT OF OTTUMWA PAVING BRICK AND CONSTRUCTION COMPANY.

The plant of this company is located in the northwest part of town, just beyond the city limits. The Coal Measure shales are finely exposed in the clay pit.

in color and composed of angular fragments from one quarter to one inch in length. Fragments of a similar rock were observed along Big branch, in Washington township, which had doubtless come from a ledge well up toward the top of the Coal Measures, though none of the limestone was here observed in place.

All the beds, whether they be shales, sandstones or limestone, are found to change rapidly when followed horizontally. No one of them is continuous over a very large area but they thin out and disappear and are replaced by other strata. Thus the shales which occur at one point will, within only a short distance, give way to sandstones or sandstone will pass into shales. The limestones likewise disappear and their place is taken by beds of different character. These lateral changes in the strata are often quite abrupt, the transition from one kind of rock to another being made within a small space. It is this changeableness of the beds which makes the correlation of the Coal Measure strata very difficult and often quite impossible. Two outcrops separated from each other by only a few yards or different parts of the same outcrop will frequently show marked differences in the succession, thickness and character of the beds. Examples of this are given under the description of typical sections. Not only do the inclosing strata vary rapidly but the coal seams themselves are not continuous for any great distance. They are more or less lenticular in shape, being thickest in the central portion and thinning out toward the edges.

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The following sections show the general character of the beds of the Des Moines stage.

I.—BEAR CREEK SECTION.

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15.	Drift	20
14.	Shale, argillaceous, gray, sandy in upper part.	20
13.	Shale, black, carbonaceous, fissile	3
12	Sandstone	3
11.	Shale, gray, argillaceous	2
10.	Shale, black, fissile, carbonaceous	5
9.	Coal, impure and bony, contains iron pyrites..	1/2
8.	Fire clay, filled with plant remains	1
7.	Shale, gray, argillaceous	5
6.	Shale, black	6
5.	Sandstone	1/3
4.	Shale, black	4
3.	Coal, bony and impure	1 1/3
2.	Shale, black, carbonaceous, fissile, rich in plant remains	1/2
1.	Shale, gray, argillaceous, exposed to creek....	20

It is probable that No. 3 is the same coal seam that is mined one mile and three-quarters northwest of here, on the opposite side of the creek. The vein there has a thickness of four and one-half feet and lies twenty-five feet above the Saint Louis limestone, as determined by test borings. The base of the above section cannot be far from the limestone, for the latter outcrops along the creek less than two miles below and rises fourteen feet above the stream.

II.—SECTION IN CLAY PIT OF OTTUMWA PAVING BRICK AND CONSTRUCTION COMPANY.

The plant of this company is located in the northwest part of town, just beyond the city limits. The Coal Measure shales are finely exposed in the clay pit.

		Feet.	Inches.
12.	Drift	3	
11.	Shale, argillaceous, gray	20	
10.	Shale, black	4 to 10	
9.	Coal	1	1
8.	Fire clay		10
7.	Sandstone, argillaceous, massive	5 to 7	
6.	Shale, black, fissile	2	
5.	Sandstone, argillaceous, gray in single ledge	4	
4.	Shale, gray, argillaceous	4	
3.	Shale, black	1	
2.	Coal	3 to 4	
1.	Fire clay	6 to 8	

The rapid change in the strata is well shown here. At the north end of the pit Nos. 4 and 5 are replaced by eight feet of black shale. No. 10 grows much thicker in the same direction, increasing from four feet to ten. No. 7 becomes thinner and

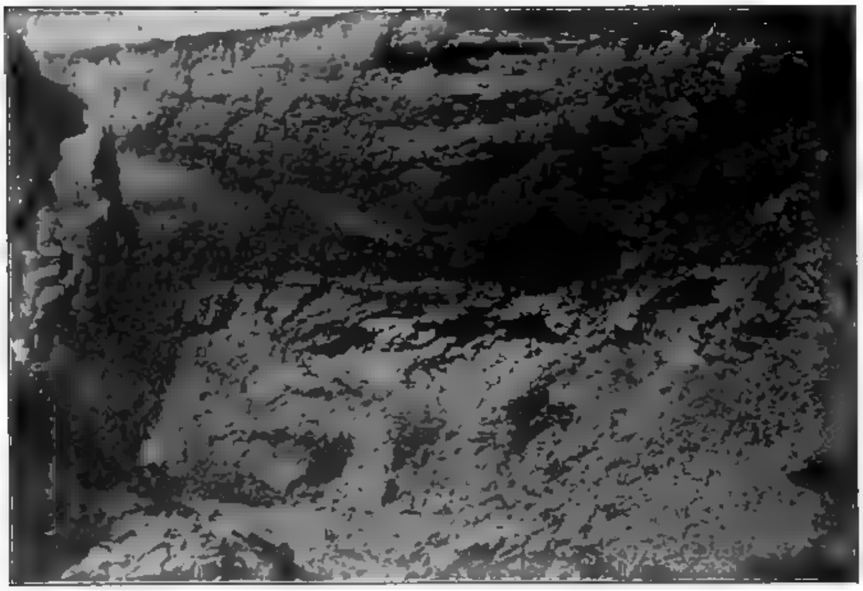


Fig. 73. The clay pit of the Ottumwa Paving Brick and Construction Company.

more shaly toward the north. All the beds in the section are used in making brick except the coal, No. 2, which has served for fuel.

III.—SECTION ON SUGAR CREEK AT THE CHICAGO, BURLINGTON AND QUINCY RAILROAD BRIDGE.

		Feet.
9.	Sandstone	10
8.	Shale, black, fissile	12
7.	Coal	2
6.	Fire clay	3
5.	Coal	2 to 4
4.	Fire clay and agillaceous shale	10 to 12
3.	Shale, black	15 to 20
2.	Unexposed	8 to 10
1.	Limestone, Saint Louis, exposed near by on creek	4

The sandstone, No. 9, increases in thickness as it is followed back into the hill.

Along the creek a short distance above the railroad bridge a four foot bed of blue, concretionary, Coal Measure limestone rich in fossils outcrops. It is not continuous over a large area, but is absent in places. Immediately below the ledge is a seam of coal from one to four feet thick which has been worked in the bed of the stream.

IV.—SECTION ON EAST BRANCH OF SUGAR CREEK, IN NW. ¼ OF SECTION 34, AGENCY TOWNSHIP.

		Feet.
5.	Sandstone, yellow, micaceous, soft, cross-bedded, contains concretions of iron	25
4.	Coal, impure, bony	2
3.	Fire clay	2
2.	Shale, argillaceous, gray	3
1.	Shale, black, carbonaceous, exposed	6

No. 5 is the same massive bed of sandstone that outcrops along the Des Moines river one mile and a half south of here. Nos. 1, 4 and 5 appear at a number of points along the east branch of Sugar creek.

V.—SECTION AT OLD COLGAN MINE, NE. ¼ OF SECTION 4, KEOKUK TOWNSHIP.

		Feet	Inches.
7.	Sandstone, massive, soft, cross-bedded	50 to 60	
6.	Shale, black	½	
5.	Coal	1	9
4.	Fire clay and argillaceous shale	15	
3.	Coal	2 to 3	
2.	Fire clay and black shale	1 to 10	
1.	Coal	4½ to 5½	

The rapid transitions which occur in the Coal Measure strata are well shown two and one-half miles below Cliffland station, along the Chicago, Rock Island and Pacific railroad (Ne. 1/4 of Sw. 1/4, Sec. 18, Tp. 71 N., R. XII. W.) Just below a narrow and steep sided ravine entering the river at this point the following section is exposed:

VI.

		FEET.
4.	Sandstone and sandy shale	37
3.	Shale, black, carbonaceous	3
2.	Coal	1½
1.	Shale, black, carbonaceous, fissile, exposed..	45

Less than 250 feet northwest of here and across the ravine the entire outcrop above the railroad track is composed of a massive sandstone which rises 100 feet above the river. The lower twenty-five feet is not exposed. The shale rises gradually above the level of the track and a one foot vein of coal lies just beneath the sandstone. The latter also contains near the bottom bands and streaks of coaly material. Less than a quarter of a mile above this section the thick bed of sandstone disappears and is replaced by shales in which are two veins of coal. The upper is eighteen inches thick, the lower is from two to three feet thick, and they are separated by four to six feet of fire clay and argillaceous shale.

VII.—BIG BRANCH SECTION.

Near the mouth of Big branch in the Ne. 1/4 of Sec. 28, Washington township, was seen the following:

		FEET.	INCHES.
6.	Drift	10	
5.	Shale, argillaceous, dark blue	2	
4.	Limestone, not continuous, concretionary..		8 to 10
3.	Shale, black, carbonaceous	10	
2.	Limestone, with several systems of joints..	1	
1.	Shale, black, carbonaceous	6	

No. 4 does not form a continuous bed but is absent in places. It forms, however, a well marked limestone horizon. No. 2 is doubtless the same stratum that appears in the bed of the river just below the mouth of Big branch.

Several years ago a number of prospect holes were put down

in the southern part of the county near Laddsdale, in sections 31 and 32 of Washington township. The holes were bored at distances of from 150 to 200 feet apart and their records are interesting as showing the character of the Coal Measure strata, especially the rapid changes in the beds, and the irregularity of the coal.

LADDSDALE SECTIONS.

A.

		Thickness in feet.	Depth.
24.	Drift	12	12
23.	Clay shale, gray and blue	13	25
22.	Shale, black	3	28
21.	Shale, sandy, gray	6	34
20.	Clay shale, blue	10	44
19.	Coal	1	45
18.	Clay shale, gray and blue	24	69
17.	Sandstone	1	70
16.	Shale, black, carbonaceous	3½	73½
15.	Coal	3	76½
14.	"Rock"	1½	78
13.	Clay shale, gray and blue	14½	92½
12.	Coal	1½	94
11.	Clay shale, gray and blue	6½	100½
10.	Shale, sandy, blue	2	102½
9.	"Rock", soft, blue	1½	104
8.	Coal	1⅓	105⅓
7.	Fire clay	2⅔	108
6.	"Rock" (limestone ?)	5	113
5.	Shale, sandy, blue	6	119
4.	Clay shale, blue and gray	16½	135½
3.	Coal	2½	138
2.	Fire clay	2	140
1.	Clay shale, light blue	12	152

B.

		Thickness in feet.	Depth.
29.	Drift	25	25
28.	Shale, black	1	26
27.	Shale, sandy, black	4	30
26.	Clay shale, gray	2	32
25.	"Rock"	½	32½
24.	Clay shale, gray and blue	27½	60
23.	"Rock," black	1	61
22.	Shale, blue	13	74
21.	Coal	1½	75½
20.	Clay shale, gray	11	86½
19.	Coal	1½	88
18.	Shale, gray	10	98

		Thickness in feet.	Depth.
17.	"Rock"	1	99
16.	Shale	4	103
15.	Coal, with rock band	3¼	106¼
14.	Fire clay	8	114¼
13.	Clay shale, blue	2¼	116½
12.	Coal	½	117
11.	Fire clay	½	117½
10.	Coal	½	118
9.	Clay shale, gray and blue	14	132
8.	Coal	1⅔	133⅔
7.	"Slate stone," black	⅓	134
6.	Shale, gray	1	135
5.	Sandstone	5..	140..
4.	Shale, sandy, blue	12	152
3.	Clay shale	6	158
2.	Coal	2½	160½
1.	Clay shale, blue and gray	16½	177

C.

15.	Drift	25	25
14.	Clay shale, blue	2	27
13.	Coal	½	27½
12.	Sandstone	4	31½
11.	"Clay rock", gray	6	37½
10.	Clay shale, gray and blue	32	69½
9.	Shale, black	2	71½
8.	Coal	1	72½
7.	Clay shale, gray and blue	28	100½
6.	Clay shale, black	2	102½
5.	"Rock"	1	103½
4.	Coal	1½	105
3.	Clay shale, blue	29	134
2.	Shale, sandy, gray	7	141
1.	Clay shale	35	176

D.

20.	Drift	20	20
19.	Clay shale, blue	5	25
18.	Sandstone	5	30
17.	Clay shale, blue and gray	33½	63½
16.	"Stone" (limestone ?)	2	65½
15.	Clay shale, gray and blue	6½	72
14.	Coal	1	73
13.	Clay shale, gray	12½	85½
12.	Coal	1½	87
11.	Clay shale, gray and blue	18	105
10.	Coal	2	107
9.	Clay shale, blue	26	133

		THICKNESS IN FEET.	DEPTH.
8.	Shale, sandy, gray	5½	138½
7.	Clay shale, blue and gray	19½	158
6.	"Cap rock"	½	158½
5.	Coal	2¼	160¾
4.	Clay shale, gray and blue	8	168¾
3.	Shale, sandy, blue	8	176¾
2.	Sandstone	5½	182¼
1.	Limestone (Saint Louis ?)	1½	183¾

A comparison of these records shows that two beds of coal were encountered in all four of the holes at approximately the same depth, namely at seventy-two and 103 feet, but that the veins varied considerably in thickness. At about 135 feet another seam was encountered in two of the holes (A and B) and at 158 feet still another was found in two of the borings (B and D) but was absent from the others. Besides the four just mentioned, other veins were struck at different depths in the various holes, no less than seven being penetrated in one boring (B) and only three in the one next to it (C) and less than 200 feet distant. These sections show that the coal beds are not persistent for any great distance and that their thickness varies quite widely.

A well sunk on the land of Norman Reno, in section 12 of Pleasant township, went through 222 feet of Coal Measures, these strata consisting of shales, without any limestones or sandstones, so far as reported. The lower 100 feet, before striking the Saint Louis limestone, was composed of black carbonaceous shale. The record of this well is given below:

		FEET.
13.	Drift clay	60
12.	Sand	3
11.	"Soapstone"	15
10.	Shale, gray	30
9.	"Soapstone"	20
8.	Shale, black, carbonaceous	7
7.	Coal	3½
6.	Shale, blue	15
5.	"Soapstone"	10 to 15
4.	Shale	8
3.	"Soapstone"	10 to 14
2.	Shale, black	100
1.	Limestone (Saint Louis) alternating with thin layers of blue "sandstone"	182

The Pleistocene System.

Separated from the Carboniferous by a long interval of time and resting unconformably upon the strata of that system are the loose, unconsolidated deposits of the Pleistocene system. These include the drift, loess and alluvium. The latter is confined to the valleys of the Des Moines and its chief tributaries and the bottom lands along Cedar and Competine creeks. With the exception of these strips along the streams the surface is covered to a greater or less depth by drift and loess.

KANSAN DRIFT.

In common with the rest of southern Iowa Wapello county is covered by the Kansan drift sheet. This is not the oldest of the glacial deposits, since at a number of localities in the state a still older drift is found beneath the Kansan and usually separated from it by a forest bed or deposit of gravel. While no evidence was found that such a pre-Kansan drift sheet is present in Wapello county it probably occurs below the Kansan, as evidence of its presence has been found in the counties lying to the east.

The drift varies widely in thickness over different parts of the area. In Center and Polk townships it is not very heavy and will probably not average much over twenty-five feet, while in Highland and Competine townships, as shown by well records, the thickness is from 120 to 130 feet. The greatest thickness reported as having been encountered in drilling wells was in section 3 of Cass township, where the drift was 170 feet. While the maximum may reach 200 feet in some places, it is likely that the average thickness is not more than 100 feet.

The materials composing the Kansan drift are clay, sand, gravel and bowlders, but the proportions in which these are found vary considerably at different points. Bowlders of any considerable size are not at all common. The largest one observed, which was beside the road in the Sw. 1/4 of the Se. 1/4 of section 32, Center township, measured six by twelve by five feet. The striations were at right angles to the surface of the ground, so that the longest diameter was doubtless buried, the striæ usually being parallel to the greatest diameter. The rock was a fine-grained

granite. Good sized diabase and greenstone bowlders were also observed.

The best place to study the drift is in the deep cuts along the new line of the Chicago, Burlington & Quincy Railroad between Ottumwa and Agency City. While these cuts were not completed when visited by the writer in June, 1902, several of them showed from forty to fifty feet of drift. In the river bluff just east of Ottumwa, at Franklin Park, the following section is exposed:

		FEET.
3.	Loess, gray, quite argillaceous, filled with plant roots	4
2.	Till, sandy, leached, reddish brown, ferruginous	[illegible]
1.	Till, blue or gray, contains but little sand and is a stiff clay (exposed)	4

The line of separation between numbers 1 and 2 is here quite distinct owing to the marked change of color. The iron has accumulated at the base of number 2, where it has been deposited in the form of limonite by descending water. It occurs in thin crusts about one-quarter of an inch thick. This middle number is also very sandy; in places it is almost a pure sand, the particles frequently being cemented together by iron. Another section which is seen in the cut one-half mile east of Sugar creek is given below:

		FEET
3.	Loess	[illegible]
2.	Till, reddish brown, leached, oxidized	[illegible]
1.	Till, blue or gray	[illegible]

Granite, greenstone and limestone pebbles are common in the lower part of the drift and many of them, save one or two, often flattened, ground and striated, through being carried along beneath the ice sheet. The loess appears to increase in thickness toward the higher ground and on the upland near Agency City is ten to fifteen feet thick.

In all of these cuts the upper weathered and oxidized zone of the Kansan drift is well shown. It indicates that after the deposition of the drift the surface of the drift was for a long period subjected to weathering agencies. The calcareous material has been dissolved out and carried away by the water and the iron constituents have been completely oxidized, giving the upper part of the till its deep red color. The depth to which this weathe-

ered zone extends, from eight to ten feet or more, indicates that a long interval of time elapsed between the deposition of the Kansan drift and the laying down upon it of the loess. The fact that the later drift sheets have undergone comparatively little change by weathering, though they were formed thousands or tens of thousands of years ago, gives some idea of what that interval must have been.

At several points a ferruginous gravel or conglomerate occurs at the base of the drift, resting directly on the Coal Measure shale. This is well shown in the Nw. 1/4 of the Nw. 1/4 of section 6, Cass township, along a tributary of South Avery creek. Here the black shales are overlain by a very ferruginous gravel and coarse, cross-bedded sand. In places the iron is so abundant as to form a cementing material for the constituent particles and a firm conglomerate or coarse sandstone is formed. The pebbles are mostly quartz and sandstone, but some are composed of igneous rock, such as diabase and granite. The presence of these foreign materials would seem to indicate that the conglomerate is to be placed with the drift rather than with the Coal Measures on which it rests, since if it belonged to the latter the constituent pebbles would undoubtedly be composed of local materials and would contain no igneous rocks brought from any considerable distance. If the conglomerate belongs with the drift series, however, these foreign pebbles are to be expected. On North Avery creek, in the Sw. 1/4 of section 26, the ferruginous gravel is again exposed at the base of the drift, which here has a thickness of six to fifteen feet. Still another locality where this deposit occurs is on the Des Moines river just above Eldon. The gravel and sand here have a thickness of ten feet; they rest on the shales of the Coal Measures and are overlain by fifty feet of drift.

The age of these gravels may be either Aftonian or Kansan. Their presence at the base of the Kansan drift, from which they are not separated by any dividing line, makes it seem quite probable that they belong with that drift sheet, though this could not be determined with certainty. It is possible that the gravels are interglacial and are to be correlated with the Aftonian gravels seen at Afton Junction and elsewhere in the state.

THE LOESS.

The loess is found overlying the Kansan drift over most of the county, though its thickness does not seem to be great. Where exposed along wagon roads and in railroad cuts it rarely exceeds five or six feet in depth, though in some places, as near Agency City, it reaches a thickness of ten to fifteen feet. The loess is light gray in color, is of fine, uniform texture and is less compact than the Kansan till. No fossils were observed in the deposit and lime concretions (loess-kindchen) are rare.

ALLUVIUM AND TERRACES.

The flood plain of the Des Moines and its larger tributaries and of Cedar and Competine creeks are composed of alluvium. This deposit is composed of materials derived chiefly from the drift and loess which have been carried down the slopes by the rains and redeposited by the streams in their valley bottoms. The alluvial plain of the Des Moines reaches a width of more than two miles for some distance below Ottumwa. The limits of the flood-plain of this river are indicated by a broken line on the map accompanying this report. Its surface lies at a level of about twelve feet above low water. The remnants of an older flood plain show at a number of places in the Des Moines valley as a terrace lying eight feet above the "first bottom," or at an elevation of twenty feet above low water. The river has cut into and carried away most of this higher plain which once formed the bottom of the valley and all that is left of it is this terrace. It appears on the west side of the river just below Ottumwa, south of Eldon, and at various points between these two towns. Eddyville is built on a terrace twenty-five feet above low water and near Kirkville station there is what appears to be the remnants of a fifty foot terrace. The road between the station and Chillicothe traverses it for some distance before descending to the present flood plain.

Deformations.

The strata have undergone but slight disturbance since they were laid down under water and for the most part are nearly

horizontal. The beds, however, have a slight dip to the south, the average being about three feet to the mile. At a few points the Saint Louis strata are seen to be thrown into gentle folds. These are well exhibited one mile northwest of Chillicothe in the artificial channel cut by the Chicago, Burlington & Quincy railroad for Avery creek. In this cut the limestone beds form five or six gentle anticlines. The monoclinal fold with a dip of 20° occuring in the same beds near Dudley, has already been mentioned.

Few faults occur in this region and when found they are of small extent. In the mine of the Illinois and Iowa Fuel Company at Keb there is a fault which has a northwest-southeast direction and a displacement of between four and five feet. A fault is also reported as occurring in the Appanoose mine at Willard.

Unconformities.

Unconformities exist between the Saint Louis limestone and Coal Measure shales and between the latter and the Pleistocene deposits. The unconformity between the strata of the Upper and Lower Carboniferous is excellently shown in the artificial cut one-half mile east of Dudley, already mentioned on a previous page, where the black shales of the Des Moines stage are seen resting on the eroded and uneven surface of the Saint Louis limestone. The calcareous beds had suffered considerable erosion and a thickness of many feet had been carried away before the shales

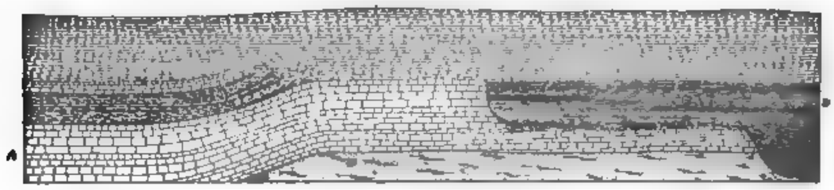


FIG. 74. Sketch showing the unconformity between the Saint Louis (A) and Coal Measures (B) as exposed in the artificial cut one-half mile east of Dudley.

were laid down on top of them. A shallow valley was cut in the limestone at this point and was subsequently filled by the argillaceous deposits of the Coal Measures (Fig. 74). The uncon-

formity is also well exhibited along the Des Moines river at the old quarry just below the Chicago, Burlington & Quincy railroad bridge.

The Pleistocene deposits everywhere rest unconformably upon the Carboniferous strata. After the latter were formed and raised above the sea there was a long erosion interval during which the land surface was carved and shaped by the streams. It is possible that there was a submergence during Cretaceous time but we have no record in this county of there being any

FIG. 75. Unconformity between the Saint Louis and Coal Measures. The limestone ledges of the former show on the left and the shales on the right. Cut near Dudley.

encroachment of the sea over this area during that period. For a long lapse of time therefore the rivers acted upon the land mass and eroded deep and broad valleys. Upon this old land surface the loose and heterogenous deposits of the Pleistocene were left by the ice sheets that invaded the region from the north.

ECONOMIC PRODUCTS.

Coal.

Wapello is one of the important coal producing counties of the state. Thirty years ago its output was greater than that of any other county with the possible exception of Mahaska, and during all the years since then it has held its place near the head of the list. It now ranks seventh in its production of coal, its output for the year 1901 being 249,880 tons.

Mining has been carried on here almost from the earliest settlement of the region. As long ago as 1857 there were mines in the neighborhood of Kirkville and Dahlonega, in the river bluffs four miles below Eddyville, and along Bear creek four miles west of Ottumwa. In 1862 Wapello produced 327,650 bushels of coal, or nearly three times as much as any other county in the state. In 1867 when White visited this district the following were the more important mines in operation: C. Dudley & Company's, one mile south of Dudley, on Middle Avery creek. The seam was four feet thick and lay fifty feet above the Saint Louis limestone. Henry Shock & Company's mines in Happy Hollow (Sec. 8, Tp. 72 N., R. XIV W.) which were working in a five foot seam. Messrs. Brown and Godfry operated the Union mine near Keb (Sec. 33, Tp. 73 N., R. XIV W.) where the coal was four to four and a half feet thick. The Alpine Coal Company had a large mine at Alpine station (two miles below Cliffland) on the Des Moines Valley railroad. The seam was from four to five feet thick and large quantities of the coal were shipped to Keokuk. White states that since the mine was opened it had produced about 1,000,000 bushels, which was probably more than the output up to that time (1867) of any other mine in the state.

In 1877 the largest mines in the county were the Union Coal Company mine with an output for that year of 608,977 bushels and the Postlewait mine in Happy Hollow with an output of 582,507 bushels. The latter mine was connected with the Chicago, Burlington and Quincy railroad, over one mile distant, by a tram

road. For a number of years prior to 1890 the Wapello Coal and Mining Company operated extensive mines just south of Kirkville (Sec. 17, Tp. 73 N., R. XIV W.) The Ottumwa and Kirkville railroad connected them with the Chicago, Rock Island and Pacific railroad and large quantities of coal were shipped. The vein averaged five and one-half feet thick and over 400 acres were worked out. Over 300 miners were employed and the total output of these mines was between one and two million tons.

Mining has been confined so far chiefly to the northwestern part of the county, in Richland, Center, Polk, Columbia and Cass townships. Aside from the Laddsdale mine and the old mine at Alpine very little coal has been taken out in the southern and northeastern portions of the county. Yet this is not because no coal occurs for seams are undoubtedly present in the Coal Measures of these parts of the area. Coal outcrops in the bluffs in the vicinity of [illegible] and there are a number of small country banks in Green township. [illegible]

[illegible]

stances lies near the surface. But when these areas have been worked out it is not unlikely that the parts which at present produce no coal will furnish a good supply. It may be expected that systematic prospecting will show the presence of workable seams in these now neglected portions of the county.

The opinion seems to be quite prevalent that coal is more liable to be present in the valleys or depressions than under the uplands. But it is to be remembered that the existing valleys and hollows were not formed until long after the beds of coal were accumulated and there is therefore absolutely no relation between the configuration of the present surface and the underlying coal seams. The latter are just as likely to occur beneath the uplands and away from the streams as anywhere else, as has many times proved to be the case.

The coal in this county lies at no great depth below the surface. There is no mine that is over 130 feet deep and most of them are less than 100 feet. In many places the seams outcrop along the sides of the valleys, as along the Des Moines river two miles below Cliffland station and at various points along Sugar creek. The lower beds of coal occur only a little above the Saint Louis limestone. In one instance the vein lies only twenty-five feet above the limestone, in another but three feet. As has already been stated the maximum thickness of the Coal Measures in Wapello county is probably not over 250 feet and over a considerable portion of the area their thickness is less than this. Beneath the uplands, therefore, where it would be necessary to to go the deepest before reaching the lower coal seams, if they were present, it might be necessary to go over 200 feet in order to strike them. To the thickness of the Coal Measures must also be added that of the drift, which averages about 100 feet. It is not at all improbable that there are coal seams lying at considerably greater depths than those now worked and that when the latter are exhausted the deeper ones will be prospected.

While the coal beds vary greatly in thickness the large majority of those which are being worked now run from four to five and one-half feet. In a few instances seams two and three feet thick are being mined, but these are exceptional. It is reported that in the Happy Hollow mine and those just south of Kirkville

the beds reached a thickness in places of six and one half and seven feet. The coal seams are not continuous for any great distance but are more or less lenticular in shape and thin out toward the sides. No one vein extends over the entire county nor probably even over one township but when followed for a few miles it is found to pinch out and disappear or to be replaced by another seam at the same or a different horizon. This comparatively rapid variation in the thickness of the beds and their thinning out toward the edges makes it necessary to put down the number of holes when prospecting for coal. A vein several feet in thickness may be struck at one point and in another hole only a few hundred feet distant the vein may be two or three inches thick or entirely absent. These irregularities in the coal seams are well known to the miners and are illustrated in the records of the borings near [illegible], given on a preceding page.

The following analyses* made by [illegible] shows the [illegible] coal as it is [illegible] the market. [illegible] average [illegible] coal [illegible] state.

[illegible]										
[illegible]										
Top of seam	[illegible]									
Middle of seam	[illegible]									
Bottom of seam	[illegible]									
[illegible]										
Top of seam	[illegible]									
Middle of seam	[illegible]									
Bottom of seam	[illegible]									

[illegible]

*[illegible]

the smaller are provided with only the simplest contrivances. In nearly one-half the mines steam power is used for hoisting the coal and in most of the remainder the horse gin is employed. For underground haulage the tail rope system is used in the Illinois and Iowa Fuel Company's mine at Keb and in the Consolidation No. 9 while in eight other mines mules are used for this purpose. The room and pillar system of mining is the only one employed in the county and the coal is shot from the solid without any undercutting. The Eldon Coal and Mining Company for several years tried the Jeffery mining machine but its use was finally discontinued on account of the stony concretions in the coal which injured the machine and caused much trouble. The coal is now mined entirely by hand. Ventilation is secured in about one-third of the mines by the use of fans and in the rest furnaces are used for this purpose. A majority of the mines are equipped with substantial and well built tipples in which stationary screens are the only ones used.

Although the seams have been worked out over only an insignificant part of the area—it is probable that not much over 1,000 acres have been mined—yet the county has yielded large quantities of coal. The output for the last twenty years is given in the reports of the State Mine Inspectors and, since 1897, in the Annual Reports of the Geological Survey. Previous to 1881 no yearly records were kept but the production for certain years is contained in the State Census Reports. In the following table are given all the available data relating to the coal output of Wapello, the amounts being stated in short tons.

YEAR.	TONS.
1860	17,062
1862	13,106
1866	6,575
1868	27,503
1874	20,745
1877	53,559
1881	131,815
1882	207,721
1883	237,821
1884	240,720
1885	187,911
1886	237,111
1887	272,073
1888	380,395

YEAR.	TONS.
1889	[illegible]
1890	[illegible]
1891	[illegible]
1892	[illegible]
1893	[illegible]
1894	[illegible]
1895	[illegible]
1896	[illegible]
1897	[illegible]
1898	[illegible]
1899	[illegible]
1900	[illegible]

The total output for the twenty years since [illegible] has been over [illegible] tons. If we add to this the estimated output for the previous years, which can be [illegible] given, but may be conservatively placed at [illegible] tons, we have a total production of [illegible] tons. It has probably been greater than this since no reports are received from many of the smaller mines and the aggregate output from these amounts to considerable in the course of a number of years. Perhaps it would be nearer the truth to estimate the total production at [illegible] tons.

It is impossible to give even approximately the amount of workable coal remaining, but it can safely be stated that there is enough to last for many years to come. Prospecting in other parts of the county that have not been worked will in all probability reveal the presence of good seams of coal.

Up to the present time mining has been carried on chiefly in the vicinity of [illegible] and [illegible] and in a strip of country between these towns. [illegible]

Of the twenty-seven mines now worked (1902) in the county seven are shipping or railroad mines and the rest supply the local trade, most of them being operated only during part of the year. Their location is shown on the map accompanying this report.

DESCRIPTION OF INDIVIDUAL MINES.

Ottumwa Mines.—Here are included all those which are within three miles of the city.

The Bear Creek Coal Company has a mine on Bear creek, three miles west of the city limits. The coal is hauled about one-half mile west to a siding on the Chicago, Milwaukee & St. Paul railroad where it is loaded on the cars. The railroad takes the entire output. The seam, which is four and one-half feet thick and outcrops on the side of the valley near by, lies only twenty-five to thirty feet above the Saint Louis limestone, being separated from the latter by fire clay and shale. The coal is reached by a slope 145 feet long and steam power is used for hoisting. The mine has been worked six years and since becoming a shipping mine is operated throughout the year.

The mine of the Star Coal Company is one and one-half miles south of Ottumwa (Sec. 2, Ne. 1/4 of the Se. 1/4.) A tramway runs from the mine to a point one-half mile nearer the city. The seam is from four feet six inches to four feet ten inches thick and is mined by a slope 400 feet long, the descent being one foot in five. Steam power is used in hoisting the coal and it is hauled by mules out to the end of the tramway.

The South Ottumwa Coal Company mine is close by the one last described and is undoubtedly in the same vein, though it here averages almost five and one-half feet in thickness. The shaft is ninety-three feet deep and coal is raised by a horse gin.

A short distance east of here is the mine of the Excelsior Coal Company (Sec. 1, Nw. 1/4 of the Sw. 1/4). The seam lies fifty-five feet below the surface and runs from four feet to four feet eight inches in thickness. Over the coal is ten feet of black shale which forms a good roof.

Still farther east, in the southwest quarter of section 6, is the John Daniels mine. This is one of the deepest in the county,

the bottom vein being 130 feet below the surface. Five feet above is another seam and the average thickness of each is four and one-half feet. The coal in this mine lies about fifty feet below the level of the Saint Louis limestone where it is exposed in the bed of the river at Ottumwa, two miles north. The limestone either has quite a strong dip to the south or the strata have here suffered considerable erosion prior to the deposition of the Coal Measures.

The four mines located south of the city find a ready market for their output in Ottumwa and are well equipped for supplying the demand.

The Fair coal mine is two and one-half miles southeast of Ottumwa, in the Ne. ¼ of the Ne. ¼ of Sec. 4, Tp. 71 N., R. XIII W. The seam is three to four feet thick and lies thirteen feet below the bed of the small stream entering the river near by. This is doubtless the same seam that has been extensively quarried in the bed of the Des Moines near the mouth of Sugar creek. The mine is worked by means of a short slope and supplies the local market.

Coal has been mined at numerous points along Sugar creek, the seam worked having a thickness of two feet. The chief mines now in operation here are the Owl Creek and Parker mines, the former being in the Se. ¼ of the Ne. ¼ of Sec. 22, Tp. 72 N., R. XIII and the latter in Se. ¼ of Nw. ¼ of Sec. 21, Tp. 72 N., R. XIII W. Coal is also being mined on a small scale from the outcropping seams in the bluff near the Chicago, Burlington & Quincy bridge over Sugar creek.

The Spring Valley coal mine is located within the city limits, near the northern boundary and on a tributary of Harrow's branch. There are two seams of coal, the upper three and one half and the lower four feet thick. The lower seam, which is the one now being worked, is reached at a depth of forty feet and lies not far above the Saint Louis limestone. The latter outcrops along the creek less than three-quarters of a mile below the shaft.

The Black Diamond mine, operated by Lumsdon Bros., is one and one-third miles northwest of the Spring Valley near the plant of the Ottumwa Paving Brick and Construction Company.

Still nearer to Kirkville, in the Nw. 1/4 of Sec. 16, is the Waddell mine, 140 feet deep and the deepest in the county. The seam is quite uniform in thickness and runs about five and one half feet, with a good slate roof. Less than a mile and a half west is the Davis mine in the northeast quarter of section 18. The new shaft is forty-three feet deep and the seam averages over five feet thick. In sinking the shaft twenty-eight feet of sandstone and four feet of shale over the coal were passed through. The Fuhs mine is located one-half mile south of Kirkville and the seam mined here is about four feet thick.

Consolidation Coal Company mine, No. 9. This mine is located two and one-half miles east of Eddyville and though the shaft is half a mile north of the line, in Mahaska county, the greater part of the present workings are to the south in Wapello county, (Sec. 3 of Columbia township). A branch of the Chicago & Northwestern railroad runs to the mine and all the coal is shipped. The seam lies near the surface and outcrops close by on the west branch of Brown creek. It averages four feet and two inches in thickness, being five feet in places. The coal is hauled over a mile from the face of the workings to the shaft by two tail ropes, the seventy horse power engine which operates one of them being located under ground. The mine is provided with an electric fan and electric signals. The seam is not level but is quite undulating so that the entries are sometimes above and sometimes below it.

Eldon Coal & Mining Company's mine at Laddsdale. This is near the Davis county line and on the Chicago, Rock Island & Pacific railroad. The shaft is on the north side of the valley of Soap creek. In sinking the new air shaft, three-quarters of a mile from Laddsdale, the following strata were passed through:

	FEET.
Blue clay (drift)	75
Sandstone	50
Shale	2
Coal	1½
Shale and fire clay	3
Coal	4⅔

Several years ago an attempt was made to use the Jeffery mining machines here but they were not a success on account of

the stony character of the coal. The railroad takes the greater part of the output and the rest is shipped to various points in Iowa and Kansas. The seam has an average thickness of four feet.

A mine was recently opened by an Eldon company on the edge of the Des Moines valley one mile east of Laddsdale. An expensive tipple was built and it was connected by a switch with the Chicago, Rock Island and Pacific. Only a little coal was taken out and the mine was soon abandoned. The roof is said to have been bad and the coal of inferior quality.

William McIntosh has a mine one mile northwest of Eldon in the Ne. 1/4 of the Se. 1/4 of Sec. 21, Washington township. There are two seams of coal in this vicinity, the upper varies considerably in thickness but is two feet in places, and from thirty to fifty feet below is the lower seam which is three feet thick at the McIntosh mine. The limestone layer outcropping along Big branch lies between the two coal beds.

Appanoose mine at Willard. This is on the Chicago, Milwaukee and Saint Paul railroad nine miles west of Ottumwa and all the output of the mine is taken by this road. The seam is four feet thick, with a depth of 100 feet. Ten feet above there is a second seam two feet thick but the coal in this is bony and unfit for use. This mine has been running about twelve years.

About one and a half miles northwest of Willard there are two local mines which have been worked for a number of years. The Newall mine is in the Ne. 1/4 of the Nw. 1/4 of Sec. 29, Polk township. The shaft is fifty feet deep and the seam averages three feet thick. The equipment is unusually good for a mine of this size, there being a well built tipple and steam power being used to hoist the coal and run the fan. A. Major and Son have a mine on South Avery creek less than one-quarter of a mile north of here, and they are probably working the same seam. Where the coal outcrops in the bed of the stream it is overlain by three inches of shale. This limestone ledge is not at all persistent and is present only in places. The seam is here mined by means of a drift and the coal is three feet and ten inches thick.

Building Stone.

Wapello county is well supplied with building stone. The Saint Louis limestone is quarried at a number of points, shown on the map at the end of this report, and the sandstones of the Coal Measures are also used to some extent, though as a rule they are too soft to be suitable for building purposes. The Pella beds of the Saint Louis stage, however, furnish a good quality of stone. It occurs in ledges varying from a few inches to two feet in thickness and many partings commonly separate the beds. The limestone is readily quarried in blocks of almost any size required for ordinary purposes and makes an excellent building material. It is of a uniform light blue or gray color pleasing to the eye, is very fine-grained and compact in texture and withstands weathering well.

The most extensive quarries are at Dudley and as they are beside the Chicago, Burlington and Quincy railroad they are well situated for shipping their products. The limestone has been quarried here for thirty years and has been extensively used by the railroad for culverts, bridges, ballast and riprap.

Fig. [illegible]. Quarry of Andrew Lames at Dudley, showing the Saint Louis beds overlain by drift.

P. W. Lyon's quarry in the north bank of Turkey Creek, section 11, Lockridge township, showing the Upper and Lower Verdi beds.

Large quantities have also been shipped to neighboring counties. T. H. Shields & Son operate a quarry near the station. About eighteen feet of drift are stripped off down to the rock and six to eight feet of limestone are exposed in the face of the quarry. A short distance west of the station Andrew Lames has a quarry in which the following ledges are seen from the top down: eighteen inches, four inches, nine inches, nine inches and eighteen to twenty-two inches thick. One-half mile south of Dudley on Middle Avery creek two new quarries have recently been opened up, one by John Swanson and the other by J. E. Ire, but little stone has been taken from them yet.

The Saint Louis beds have been quarried at several points in the vicinity of Chillicothe and on South Avery creek. In the Se. 1/4 of Sec. 35, Tp. 73 N., R. XV W., twenty feet of limestone are exposed along the creek and considerable of it has been taken out here. There are several quarries near the mouth of Rock run in the Sw. 1/4 of the Nw. 1/4 of Sec. 15, Tp. 72 N., R. XIV W. The Saint Louis strata are well exposed on both sides of the stream and the section seen here has already been given on a previous page.

C. B. Castle has a quarry on Bear creek just west of the city limits of Ottumwa. It is close to the Chicago, Milwaukee and Saint Paul railroad.

Limestone has for many years been taken from the bed of the river at Ottumwa during low water. A new place is opened up and worked out each season. That portion of the bed of the stream which is to be quarried during the summer is enclosed by an embankment to keep out the water. This is constructed of barrels filled with clay against which are piled broken stone, gravel and sand until a substantial barrier is built up. About six feet of limestone is removed, the upper layers being thin-bedded and the lower in ledges three to eight inches thick. The quarry is operated by Charles Chilton and during the past year (1901) it was a short distance below the new wagon bridge.

Limestone is also quarried quite extensively on Harrow's branch, one-quarter of a mile above Second street, in the northwestern part of Ottumwa.

Across the Des Moines river from Eddyville and three-quarters

of a mile south of the town there are two quarries near the mouth of Miller creek. Thomas Cawley has one near the river and a short distance south is another belonging to John Lafferty. The

FIG. 77. Quarry in bed of the Des Moines river at Ottumwa.

Saint Louis beds here rise fifty feet above the river and are found outcropping well up in the bluff. Considerable stone has been taken out from both of these quarries and most of it used in Eddyville and vicinity, though some has been shipped. Where the Saint Louis strata outcrop on the stream two miles south of Kirkville, near the center of the northeast quarter of section 20, Richland township, the rock has been quarried for a distance along the creek. From the bed of the Des Moines river below Eldon and just north of the Davis county line quite a large quantity of limestone is annually taken out during the season of low water.

In the above list are not included all the locations where limestone has been quarried in the county, for the rock has been taken out at numerous points throughout the area covered by the

Saint Louis and it would not be possible to give all of these even if it were worth while.

The value of the limestone quarried in Wapello county during 1901 amounted to $14,757, a slight increase over the preceding year.

Clay.

The clay industry of Wapello county is an important one and within its borders is located one of the largest and best equipped brick plants in the state.

Three kinds of clay are found in the county, namely: 1, Coal Measure shale; 2, drift clay and 3, alluvium. All three of these materials are used at one or the other of the clay works. The shales outcrop at many points along the Des Moines and its tributary streams and a number of sections containing these were given under the discussion of the Coal Measures. The drift clay that is utilized is mostly the loess overlying the Kansan drift and forming the surface deposit over nearly the entire area. The alluvial clays are confined to the valleys of the principal streams, being especially abundant along the Des Moines.

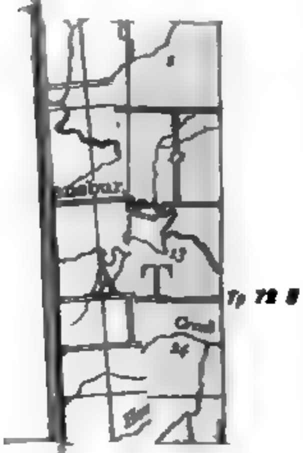
Ottumwa Paving Brick and Construction Company.—The plant of this company is located just beyond the northwestern corner of the city limits of Ottumwa. It is not far from the Chicago, Milwaukee and Saint Paul railroad with which it is connected by a switch. In the clay pit, which is in the side hill just back of the works, there are exposed over fifty feet of Coal Measure shales and these are all used as they come, from the top to bottom. The section shown here is given on page 466 of this report. From that it will be seen that a variety of strata occur in the pit; clay shale, sandy shale and sandstone, black, fissile, carbonaceous shale, coal and fire clay being present. The lower coal seam has been mined and used for fuel. Most of the fuel, however, is obtained from the Black Diamond mine, only a short distance from here. This brick plant, the most important in southern Iowa, is finely equipped and no expense has been spared on buildings or machinery. The brick are burned in an immense continuous kiln 160 feet long and eighty-six feet wide, with a total capacity of 704,000 brick. It has twenty-two tunnels or arches, each with a capacity of 32,000. As

is customary in kilns of this type the firing is done from the top. The coal is ground fine in the dry pan used for the clay and is fed in a little at a time. The finer the coal the more perfect is the

FIG. 78. Plant of the Ottumwa Paving Brick and Construction Company. The large continuous kiln is shown at the right.

combustion and the fact that the thin cloud issuing from the 100 foot smoke stack of this kiln is almost white is evidence that most of the carbon is consumed and but very little escapes. This continuous kiln is the largest in Iowa and is said to be one of the largest in the world. In addition to it there are five Eudaly down-draft kilns and one open updraft kiln. Both the Penfield and the Brewer brick machines are used, and the former being employed for making end-cut brick. There is in use a nine-foot dry pan made by the Eagle Iron Works of Des Moines. In the large brick dry-shed provided with six miles of steam pipe, 50,000 brick are dried every twenty-four hours and this is about the daily production of the plant. Power is furnished by three boilers of eighty horse power each and engines of over 170 horse power.

The product of the plant is building brick of excellent quality, hollow blocks and pavers. The latter are made from the fire



BY

A. G. LEONARD

1902.

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

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Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles.

clay which occurs in the bottom of the pit below the lower coal seam.

The Swift, Campbell Brick Company.—This company has a brickyard just east of the city limits between the tracks of the Chicago, Burlington and Quincy and the Chicago, Rock Island and Pacific railroads. The plant has been in operation two seasons. The alluvial clay which is used is obtained near by, the yard being located on the edge of the flood plain over which the alluvium has been deposited by the river. The thickness of the deposit is from ten to fourteen feet and below the clay is a layer of water-bearing sand. The clay grows sandy toward the bottom and the lower two or three feet are very arenaceous. Some of this sandy material is mixed with the clay to prevent it from shrinking too much in drying. Most of the brick are burned in a large continuous kiln with ten arches. This is provided with the Swift coking tables on which the coal is first coked and then pushed over either side on to sloping grates where it is consumed. In addition to the large kiln there are three open updraft kilns. A Brewer No. 6 brick-machine is used and the brick are dried in long sheds open at the sides.

Ostdeik Brick Plant.—This is located in the northeastern part of Ottumwa a short distance north of Pennsylvania avenue. It is the oldest brickyard in the county and has been running thirty-two years. Eighteen inches of surface clay or loess is used and in the common brick no other material is mixed with this. But in those of better quality one part of fire clay is mixed with four parts of loess. An Anderson brick machine, made in Anderson, Indiana, is in use here. The moulds are sanded and it is this sand on the surface of the bricks that gives them their red color. They are dried in sheds, partly by exhaust steam, partly by the wind and are burned in four open updraft kilns.

Mr. A. W. Melchor has a tile-yard at Phillips, just across the Chicago, Milwaukee and Saint Paul tracks from the coal mine of the Phillips Fuel Company. The plant has been in operation fourteen years. Surface clay or loess to a depth of three feet is used and with this is mixed from one-third to one-fifth of fire clay. A Brewer machine is employed and the tile are burned in one large and one small round downdraft kiln. Sizes varying

from one and one-fourth inches to ten inches in diameter are made. These tile are of superior quality, hard, tough and of uniform grade and size. They are burned two days. There was formerly a brick yard at Eldon but it is no longer in operation.

The value of the clay products of Wapello county for 1901 amounted to $64,093 or an increase over the previous year of more than $20,000.

Water Supply.

The many streams of the county furnish an abundance of water for stock and other purposes during all but very dry seasons. The summer of 1901 was such an exceptional season and the drouth continued so long that most of the streams dried up entirely. The chief source of water supply for domestic use, however, is from wells. The water is found at varying depths in sand and gravel layers in the drift. Some of these drift wells are 130 feet or more in depth while others extend down only ten or twenty feet. At a number of points in the northeastern part of the county the water is found in a bed of sand at or near the base of the drift. In sections 10 and 12 of Highland township this sand layer was struck at a depth of about 120 feet. A well one mile south of Marysville went through about 130 feet of drift and did not reach the Coal Measure shales.

Quite a number of wells have been sunk to the Saint Louis limestone and a few have penetrated to the deeper strata of the Mississippian series. One of the important water horizons of this region and one carrying an abundant supply, is a sandstone about twenty feet below the top of the Saint Louis beds. This sandstone probably belongs to the Verdi division of that stage. A well in the northwest quarter of section 27, Green township, struck the Saint Louis at 350 feet and the water-bearing sandstone at 370 feet. The water rose to within 170 feet of the surface. Near Blakesburg the limestone was struck at a depth of 365 feet. The well at the county poor farm, in section 22 of Highland township reached the sandstone at 246 feet, having encountered the Saint Louis at 226 feet. Two miles northeast of Munterville, in section 9 of Polk township water was found at a depth of 124 feet, after going through twenty-four feet of lime-

stone. Another well one and a half miles east of Munterville struck the Saint Louis at 210 feet and penetrated it twenty feet when an abundant supply was found. One of the deepest wells in the county is on the farm of Norman Reno in section 12 of Pleasant township. The record of it has already been given on a previous page. Its depth is 470 feet and the last 182 feet were through beds of the Mississippian series. In the city of Ottumwa there are three artesian wells, one belonging to Morrell & Company and two to the Artesian Well Company. The former is 1,554 feet and the latter 2,047 feet deep. The water from the wells of the Artesian Well Company is piped to about 200 store buildings and houses and is said to be used by over 2,000 persons. The following testimonial, dated September 1, 1893, is signed by fifteen of the physicians of the town:*

"We recommend the Ottumwa artesian water as absolutely pure, and coming from a depth of 2,547 feet, free from all organic matter. The exclusive use of it would do away with typhoid fever entirely, so far as danger from drinking water is concerned, and greatly reduce the amount of sickness from other diseases. It is not only of great value as drinking water, but has a remarkably beneficial effect on cases of chronic rheumatism, constipation and many forms of stomach and kidney troubles."

An analysis of the water from this well is given below, No. 1. As examples of the character of local waters from the Mississippian beds analyses of two waters from the Mineral Springs Sanitarium at Ottumwa are added. No. 2 is from a depth of 314 feet, and No. 3 from a depth of eighty-five feet.†

* Norton: Artesian Wells of Iowa; Iowa Geol. Surv , Vol. VI, p. 318, Des Moines, 1897.
† Iowa Geol. Surv., Vol. VI, p. 318, Des Moines, 1897.

COMPOUND.	GRAINS PER GALLON.		
	NO. 1.	NO. 2.	NO. 3.
Calcium carbonate	13.20	22.265	7.844
Magnesium carbonate	3.27	30.802	5.294
Iron carbonate	......	2.940	.184
Sodium carbonate	......	....	10.212
Calcium sulphate	......	38.230	......
Magnesium sulphate	6.10	....	......
Sodium sulphate	33.83	200.875	18.105
Potassium sulphate	......	2.231	Trace
Sodium chloride	11.48	51.805	2.700
Silicia	......	7.299	1.443
Alumina	....	Trace	Trace
Organic matter	......	Trace	Trace
Loss	......	....	.662
Total	68.000	356.477	41.444

No. 1. Analyst, Professor L. W. Andrews, Iowa City; date, December 12, 1893; authority, circulars of company. (There seems to be some omission in the published analysis, as the total of the compounds is 67.88, instead of 68.)

No. 2. Analyst, D. D. Carter, Omaha; authority, circulars of company.

No. 3. Analyst, S. R. Macy; authority, circulars of company.

In South Ottumwa and elsewhere in the valley of the Des Moines an abundant supply of excellent water is reached at a depth of twenty-two to twenty-six feet. It occurs in a layer of sand which underlies the alluvial clays.

Soils.

The soils of Wapello county belong to two types and both of them have been formed from the Pleistocene deposits. As has already been stated the entire region is covered with Kansan drift over which the loess forms a thin mantle, in many places not over five feet thick. This loess differs from that found along the Mississippi and Missouri rivers in being more clay like and less porous. The particles composing it are finer than those constituting the more typical variety. The soils of the county are for the most part a modified loess. Its upper part has been more or less leached and oxidized and mingled with decayed vegeta-

tion, which carbonaceous material gives it the dark color and adds greatly to its fertility. Evidence of the richness of this soil is furnished by the prosperous farms with their large and substantial buildings which are to be seen on every hand.

In the broad valley of the Des Moines and along many of the larger streams the soil is formed of alluvial deposits and is a rich black loam. This has been derived from the uplands and from the slopes whence it has been washed by the rains and redeposited by the streams. This alluvium forms a soil of great fertility and since additions are made to it from time to time during periods of flood, it is practically inexhaustible.

Road Materials.

The question of good roads is yearly becoming a more important one as the great benefits derived from them are more clearly realized. Before many years have gone by it will be a practical question with many a community as to where it can secure cheaply good road materials. Some parts of Wapello county are well supplied with such materials. Wherever the Saint Louis limestone occurs it will furnish abundance of stone for macadamizing the roads. The sandstones of the Coal Measures are for the most part too soft and friable to be of service in road making. Deposits of gravel are not common in the county, but where they do occur they supply excellent material for this purpose. A gravel pit near Eddyville has furnished ballast for the railroad, and the Saint Louis limestone has been crushed for the same purpose. Another material which has been extensively used by the railroad for ballast is burnt clay. The stiff, gumbo-like clay, which is common in southern Iowa, is thrown into piles and burned until hard, when it forms an inexpensive and serviceable ballast.

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